Best Management Practices for Mosquito Control

Washington State Department of Ecology
Water Quality Program

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Introduction

On April 10, 2002, the Washington State Department of Ecology (Ecology) issued a general permit (NPDES Permit No. WAG-992000) covering all mosquito control activities that discharge insecticides directly into surface waters of the state. Under the permit, the use of insecticides for mosquito control in water is allowed when the effects are temporary and confined to a specific location, though locations where insecticides are used may be widespread throughout the state. Applications of insecticides are subject to compliance with Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) labels, monitoring/reporting requirements, and the implementation of best management practices (BMPs) that include a hierarchy of preferred integrated pest management options.

Since the issuance of the permit, the focus of mosquito abatement has grown from being primarily a nuisance control issue to a widespread human health concern. The West Nile virus, a mosquito-borne disease that has been steadily spreading westward across the United States since 1999, reached Washington State in the fall of 2002. A raven from Pend Oreille County and a crow from Snohomish County collected as part of a statewide dead bird surveillance effort tested positive for the virus. A horse in Island County and a horse in Whatcom County also tested positive. These are the first detections of West Nile virus in our state. Transmitted by mosquito bites to humans, the virus has proven itself a low risk public health threat. As of November 26, 2002, nearly 4000 human cases of the illness have been reported nationwide to the Center for Disease Control and Prevention; and as of January 29, 2003, there have been 259 fatalities. In looking at the progress of the virus as it has spread across the United States, it appears that mosquito control efforts have no effect halting the continued spread of this virus. Control efforts can, however, reduce the risk of exposure in some cases.

Due to the human health threat posed by mosquitoes, many local governments and others are now preparing to conduct mosquito control activities, focusing primarily on education and surveillance. Many are also gearing up to respond to disease outbreaks by larviciding and are pursuing permit coverage to perform these activities in surface waters. Since these activities are projected to be widespread and often conducted by entities with limited budgets, Ecology has taken the lead on preparing the best management practices (BMPs) required by permit condition S4.

These BMPs will be available to any entity that chooses to adopt them. Mosquito control entities that wish to develop their own BMPS may do so, but they must be approved by Ecology. An approvable integrated pest management (IPM) program for mosquitoes should include all the features of IPM as defined in Washington State law (RCW 17.15.010) and adapted to mosquito management:

1) Minimization of mosquito breeding sites,
2) Monitoring for high mosquito populations and disease,
3) Establishing the targeted density of the population based on health, public safety, economic and aesthetic thresholds,
4) Treating mosquitoes to reduce populations below the targeted threshold using strategies that may include biological, cultural, mechanical, and chemical control methods and that must consider human health, ecological impact, feasibility, and cost effectiveness, and
5) Evaluating the effects and efficacy of pest treatments.

The draft BMPs were the result of a collaborative effort among the Departments of Health, Agriculture, Fish and Wildlife, and Ecology; King County; Washington State University; and several Washington-based mosquito control districts. These final BMPs have been modified and, we believe, improved thanks to the many comments given to us by mosquito control experts and others who took the time to review the draft and offer their expertise and suggestions. Their comments and the responses to those comments can be found in the Response to Comments section at the end of this document.

Mosquito Management Entities

When individual protective efforts are not sufficient, public agencies that are either components of local health departments or are independent districts organized specifically for mosquito control can provide an effective way to manage mosquito infestations on an area-wide basis. In some cases, individuals, communities, and other organizations may want to hire private mosquito control applicators for targeted treatments. However, if long-term mosquito management is desirable, establishing a mosquito control district may be the best and most cost-effective alternative.

In Washington, local mosquito control districts are organized under RCW 17.28. Unless a district is formed under RCW 17.28 or a public health emergency is declared, it is unlawful to treat the property of individuals without their permission. This regulation gives districts authority to spray those areas where excessive infestations are occurring, even if property owners do not want their property sprayed. The ability to enter onto private lands for mosquito control requires that a resolution be adopted by a mosquito district. There may be valid safety reasons why a landowner does not allow access to a piece of property. As an alternative, the regulation states that the local mosquito control board may require the landowner to control mosquitoes. We recommend that federal, state, and tribal land managers be consulted prior to any treatment on these lands.

The formation of mosquito control districts can provide a self-taxing, long-term method of mosquito control, but it may take up to two years to form a district. In the short-term, local public health entities may need to take effective abatement measures. Abatement programs can be organized, and abatement treatments performed, on cooperating property owner sites. Effective abatement programs start with a preliminary assessment and the development of an implementation strategy, including public education and outreach, and progressively lead up to organizing treatment responses.

Mosquito Life Cycle and Biology

There are several species of mosquito that readily attack people, and some species are capable of transmitting microbial organisms that cause human diseases such as malaria and encephalitis. The mosquitoes of major concern in Washington belong to the genera *Culex*, *Culiseta*, *Aedes*, *Ochlerotatus,* and *Anopheles*.

Mosquitoes are classified as insects of the *Diptera* order. They undergo a complete metamorphosis, which involves four stages of development: egg, larva, pupa, and adult. The first three stages occur in water, but the adults are active flying insects. The female feeds upon the blood of humans and animals before laying eggs directly on water or on moist substrates likely to become flooded with water.

Eggs later hatch into larvae, the stage they are most vulnerable to control efforts. During the larval stage, they continue to feed and grow in size. Larvae go through four growth stages called instars. Once larvae have developed to the fourth instar, they stop feeding and transform into pupae where internal changes occur and adult mosquitoes take form. This is a resting period. At this point, bacterial larvicides no longer work as a control measure because they require ingestion by the organisms; however, monomolecular surface films and petroleum distillates are effective on pupae. Draining or emptying the water at this point will also kill the pupae, as they are unable to live out of water. After a few hours to a few days in the pupal stage, the adult mosquito emerges from the water surface and seeks shelter in shady, moist areas. Adult mosquitoes must find shelter during the heat to avoid dehydration and are most active from dawn to dusk. After a brief period of rest, the adult female goes in search of a blood meal and the cycle continues. The time frame for this is highly variable, anywhere from one to three weeks, depending on the temperature of the water. The warmer the water, the quicker the development will be. A small amount of water in a container in the sun will produce a batch of adult mosquitoes very quickly.

Mosquito biology can follow two general scenarios. The first involves those species that lay their eggs in masses or rafts on the water's surface. These species, found throughout the U.S., often lay their eggs in natural pools, puddles, or man-made water-holding containers. In summer the entire life cycle, from egg to adult, may be completed in a week or less.

The second scenario involves *Aedes* mosquitoes that lay their eggs on moist soil or other substrates periodically flooded with water. After about two days in water, these eggs are ready to hatch, but if not flooded, can withstand drying for months and longer. In inland areas of the U.S. where these mosquitoes breed, heavy rains and flooding can produce millions of mosquitoes in a short time. Similar situations occur along coastal areas with mosquitoes adapted to salt marsh habitats. Some salt marsh mosquitoes are strong fliers that can travel up to 50 miles from the breeding site.

The main concern with the use of authorized insecticides is the long-term adverse impact from efforts to eradicate mosquitoes, especially impacts to nontarget organisms. Other species which may be inadvertently killed by a mosquito pesticide (nontarget species) include other insects, daphnids (water fleas), flies, copepods, mysid shrimp, and many others. Agents that kill mosquito larvae may also kill these related beneficial species. Many animals such as fish and birds depend on these species for food. Plants depend on mosquitoes and many of these other species for pollination. Effects other than death may also occur in nontarget species from compounds such as methoprene, which is an endocrine disruptor (disrupts glandular secretions of hormones).

Nontarget species that live in water include some of the most important food items for small fish and the young of larger fish such as salmon. Daphnids and the larvae of insects are particularly important fish foods. This is the reason the United States Environmental Protection Agency (EPA) included daphnids in its manuals for aquatic toxicity testing and insect larvae for sediment toxicity testing. If the populations of these important organisms are reduced in a water body due to mosquito control agents, then small fish there may starve. These small fish would also eat mosquito larvae. Other predators of mosquitoes such as dragonflies and copepods could also be reduced. If there are fewer predators of mosquitoes, the need for pesticides to control them can become greater. It becomes a vicious cycle.

IPM-based Best Management Practices

Current interest in the environmental impacts of mosquito control measures and increasing problems that have resulted from insecticide resistance emphasize the need for "integrated" control programs. Integrated Pest Management (IPM) is an ecologically-based strategy that relies heavily on natural mortality factors and seeks out control tactics that are compatible with or disrupts these factors as little as possible. IPM includes the use of pesticides, but only after systematic monitoring of mosquito populations indicates a need. Ideally, an IPM program considers all available control actions, including no action, and evaluates the interaction among various control practices, cultural practices, weather, and habitat structure. This approach thus uses a combination of resource management techniques to control mosquito populations with decisions based on surveillance. Fish and game specialists and natural resources biologists should be involved in planning control measures whenever delicate ecosystems could be harmed by mosquito control practices. We recommend that WDFW and other resource management agencies (including National Marine Fisheries Service and U.S. Fish and Wildlife Service) be consulted to determine when and where operations may harm delicate ecosystems, as well as appropriate treatments in these situations.

An integrated pest management program for mosquitoes should include all the features of IPM as defined in Washington State law (RCW 17.15.010) and adapted to mosquito management:

1) Minimization of mosquito breeding sites,
2) Monitoring for high mosquito populations and disease,
3) Establishing the targeted density of the population based on health, public safety, economic and aesthetic thresholds,
4) Treating mosquitoes to reduce populations below the targeted threshold using strategies that may include biological, cultural, mechanical, and chemical control methods and that must consider human health, ecological impact, feasibility, and cost effectiveness, and
5) Evaluating the effects and efficacy of pest treatments.

Goals, Logistics, and Action Threshold Determinations

The goal of BMP-based mosquito control efforts is to achieve a level of control sufficient to maintaining an acceptable level of risk (exposure to vector and/or nuisance adult mosquitoes) with the least possible adverse impact to the environment.

Success at meeting that goal will depend on several factors. First, securing long-term funding will be necessary, by forming a self-taxing mosquito control district or creating a funded program housed in a government agency. In addition, applications of insecticides to water must be made by individuals licensed by the Washington State Department of Agriculture and permitted by the Department of Ecology's Water Quality Program. Individuals and organizations conducting mosquito control activities must be licensed and permitted before insecticide activities can commence, a process that takes at least 38 days. Information on WSDA license requirements is online at http://pep.wsu.edu or call WSDA toll-free at (877) 301-4555. Permitting information is available from Ecology's website at www.ecy.wa.gov/programs/wq/pesticides/index.html or call (800) 917-0043.

Appropriate mosquito management strategies vary depending on action threshold determinations (see below), the size and type of area to be treated, the species of mosquito, and the stage of the mosquito life cycle being targeted. Mosquito control programs include source reduction, surveillance, the use of a variety of mosquito control strategies, and ongoing evaluation. While education provides individuals the most personal protection, the underlying philosophy of mosquito population control is that the greatest control will occur when the mosquitoes are concentrated, immobile, and accessible. This emphasis focuses on habitat management and controlling the immature stages before the mosquitoes emerge as adults. Under these conditions, insecticides are dispersed only where mosquito larvae are present and not indiscriminately, which is why larviciding is much sounder than adulticiding.

Mosquito control agents and/or the sponsors who hire them must set action level thresholds to determine when appropriate area-wide efforts should be triggered. The action level thresholds proposed in this model BMP plan for mosquito control may be adopted, or modified as needed and then adopted, by all mosquito control entities covered under Ecology's permit: Aquatic Mosquito Control National Pollutant Discharge Elimination System Waste Discharge General Permit No. WAG – 992000 (Permit). *Entities wanting to set action level thresholds other than those proposed here or those who wish to develop their own BMP/IPM plan must have their individual plans approved by Ecology before they can apply pesticides to surface waters in Washington State.*

BMPs for Mosquito Control

I. Minimization of Mosquito Breeding Sites and Biting Opportunities

Risk Assessment: Probability of outbreak in humans: Remote
Action threshold: The presence of mosquitoes (any species) or any suspected presence of mosquitoes in the area of control may trigger minimization efforts in the early spring and summer. The mean development time from egg hatch to pupation takes 5 to 10 days at temperatures near 25º C (77º F) (Pratt and Moore, 1993). However, certain species of eggs can hatch in water as cold as 45º F (Lilja, 2002, p. 24). Minimization actions, therefore, are most effective when taken in the early spring and continued through fall on an as-needed basis.
Rationale: Because mosquito-borne diseases have been positively identified in Washington State, measures to educate people about minimizing mosquito breeding sites and biting opportunities around homes and offices should be adopted. Minimizing breeding sites in the targeted area of control and personal protection, especially for those with compromised immune systems, are the best defenses against exposure, giving the best protection for the least cost.
DOH Recommended Response: Obtain surveillance and control resources to enable emergency responses. Initiate community outreach and public education programs. Conduct entomologic surveys (inventory and map mosquito populations) and monitor avian mortality, human encephalitis/meningitis, and equine outbreaks (Lilja 2002, p. 16).
Minimum BMP Response: Conduct education and outreach appropriate to the area of control, enlisting assistance from local government (*i.e.,* the local environmental health department), if possible. Track reports in the local area for avian mortality, human encephalitis/meningitis, and equine surveillance.

A. Minimization techniques for mosquito control around *private homes or offices* primarily involve educating those in the area of control about eliminating mosquito breeding sites, using repellents and protecting domestic animals. The following is a general list of actions that can be taken around private homes and offices. Additional information is available from the federal Centers for Disease Control and Prevention at http://www.cdc.gov/ncidod/dvbid/westnile/index.htm

- Empty or turn over anything that holds standing water—old tires, buckets, wheelbarrows, plastic covers, and toys.
- Change water in birdbaths, fountains, wading pools, and animal troughs weekly.
- Remove all human-made potential sources of stagnant water where mosquitoes might breed.
- Drill holes in the bottoms of containers that are left outdoors.
- Clean and chlorinate swimming pools that are not in use and be aware that mosquitoes can breed in the water that collects on swimming pool covers.
- Aerate ornamental pools and use landscaping to eliminate standing water that collects on your residence; mosquitoes can potentially breed in any stagnant puddle that lasts more than 4 days.
- Recycle unused containers—bottles, cans, and buckets that may collect water.
- Make sure roof gutters drain properly, and clean clogged gutters in the spring and fall.
- Fix leaky outdoor faucets and sprinklers.
- Keep all ornamental shrubs and bushes trimmed and pruned to open them up to light and air flow. This will not only give mosquitoes fewer places to hide, but will promote growth and vigor in the plants.

- Stock water gardens *that have no surface outlet* with mosquito-eating fish recommended by the State Department of Fish and Wildlife (*i.e.,* goldfish, mud minnow, stickleback, and perch). Tadpoles, dragonfly larvae, diving beetles, back swimmers, and front swimmers also prey on mosquito larvae. For more information, contact your nearest Regional Office of the Department of Fish and Wildlife"
- Make sure window and door screens are "bug tight." Repair or replace if needed.
- Stay indoors at dawn and dusk when mosquitoes are the most active.
- Wear a long sleeve shirt, long pants, and a hat when going into mosquito-infested areas such as wetlands or woods.
- Use mosquito repellant when necessary, and carefully follow directions on the label.
- To protect your horses and other equines, talk to your veterinarian about the West Nile virus vaccine. The vaccine requires two doses three to six weeks apart, and immunity may not be achieved until up to six weeks after the second dose. An annual booster should be given a few weeks to a month prior to the start of the mosquito season in your area.
- Veterinarians should be consulted if you have concerns about your household pets or other animals. Repellents may be used in some instances.
- Thoroughly clean livestock watering troughs weekly.
- Do NOT drain or fill wetlands. Wetlands perform at least three classes of functions: hydrologic functions (*i.e*., flood peak reduction, shoreline stabilization, or groundwater exchange), water quality improvement (sediment accretion, filtration or nutrient uptake), and food-chain support (structural and species diversity components of habitat for plants and animals, including threatened endangered and sensitive species). Given the critical functions wetlands perform, Ecology does not condone draining wetlands as a method for mosquito control. Since most predation on mosquitoes occurs when they are larvae, the best mosquito control is to target the larvae, either by fostering predators native to the area of control (amphibian larvae, aquatic salamanders, small fish) or by selective larvicides such as BTI. Wetland literature suggests that dragonflies are probably the only significant predator on adult mosquitoes. Mosquito "outbreaks" occur in destabilized wetland and stream ecosystems where the predators of the larvae are excluded. It is the wetlands we have changed and tampered with that tend to have the most mosquito problems (Tom Hruby, Ecology Wetland Specialist, personal communication 2/26/03).

B. Mosquito control in *wide areas* involves educating those in the area of control about reducing mosquito breeding sites, using personal protection, and protection techniques for domestic animals. Education may need to be targeted to specific areas such as new construction, drainage and water treatment facilities, residential and light commercial occupants, farms, and irrigation districts.

- Education/information on breeding site minimization and personal protection must be provided to people residing in the area of control (see list above). A significant management strategy for controlling mosquitoes is to enlist residents and businesses in the control of larvae around their homes and offices. Many people unknowingly contribute to mosquito problems by not taking steps to minimize breeding sites and biting opportunities. Federal, state, and local health departments often have publications and other materials that explain how people can protect themselves and minimize breeding.
- Education/information must be provided about risks to domestic animals, vaccinations and repellents available as well as minimization techniques specific to the area where domestic animals may reside. Direct people to their veterinarian for more information.

- As new facilities are being designed, consideration should be given to reducing mosquito habitat as much as possible.
- When considering a drainage or water treatment facility for mosquito control, the first consideration should be whether the problem could be reduced by physical modification or repair without compromising the facility's function. Physical modifications should be designed by an engineer and reviewed by the local government to insure they meet applicable design requirements. A possible design modification may include scarifying the pond bottom where it is no longer infiltrating as originally designed or enhancing infiltration by some other method. Eliminating low spots that collect small amounts of standing water and altering excessive overgrown vegetation may also be options. Alterations of slopes or repairs to a facility should not involve a reduction in the water retention or carrying capacity of the facility. As an example, soil should not be added to fill low spots. Instead, low spots should be graded flat such that the carrying capacity is not reduced.
- Ponds may be stocked with mosquito-eating fish, copepods or other predators recommended by the Washington Department of Fish and Wildlife (i.e., mud minnow, stickleback, and perch). Tadpoles, dragonfly larvae, diving beetles, back swimmers and front swimmers also prey on mosquito larvae. For more information, contact your nearest Regional Office of the Department of Fish and Wildlife.
- Over-watering and poor irrigation practices are common producers of mosquitoes around the home, in parks, in irrigated fields, and on golf courses. Report standing water to appropriate maintenance personnel.
- Irrigated lands are among the highest producers of mosquito breeding sites in Washington State. High numbers of mosquitoes can develop in standing water as a result of flood irrigation. The actions below can help eliminate mosquito breeding sites by using physical controls (Colorado, 2002; Pratt and Moore 1993).
  1) Minimize standing water in fields so that it does not lie fallow for more than four days by improving drainage channels and grading.
  2) Tail waters should not be allowed to accumulate for more than four days at the end of the field.
  3) Keep excessive overgrown vegetation out of ditches to promote more rapid drainage, but retain ground cover to prevent soil loss.
  4) Have ditches repaired to reduce seepage to the extent practicable (elevated water tables can produce unintended standing water in fields). Modification or repairs to a ditch should not reduce the carrying capacity.
  5) Minimize flood and rill irrigation practices to the extent practicable.
  6) Avoid over-watering.

Note: *Wetlands and greenbelts should not be drained or removed.* See Wetland bullet under A. Wetlands cleanse and slowly release rainwater and provide flood protection and wildlife habitat. Many wetlands recharge ground water critical for local drinking water supplies and prevent streams from drying up during the summer. We will not eliminate mosquitoes by draining wetlands and removing greenbelts. In fact, we could actually increase the mosquito population if their natural predators are destroyed because many mosquito species need only a small puddle or depression to breed.

II. Monitoring for Mosquito Populations and Disease

Risk Assessment: Probability of outbreak in humans: Remote to low

Action threshold: The presence of vector or nuisance mosquitoes suspected or confirmed in the area.

Rationale: Base-line data on mosquito populations from a variety of habitats will help target educational efforts and are essential to control efforts, should they become necessary.

DOH Recommended Response: Obtain surveillance and control resources to enable emergency response. Increase larval control and source reduction and public education emphasizing personal protection measures, particularly among the elderly. Enhance human surveillance and activities to further quantify epizootic activity, such as mosquito trapping and testing. Consider targeted adult mosquito control if surveillance indicates high potential for human risk to increase.

Minimum BMP Response: Conduct outreach and education; monitor and track avian mortality, human encephalitis/meningitis, and equine surveillance in the area of control. Conduct entomologic surveys (inventory habitats and map mosquito populations).

A. Monitoring for high mosquito populations and disease *around private homes or offices*:

- Contact your local health department for information about birds, horses, and humans found to test positive for West Nile virus or other mosquito-borne diseases in your area of control.
- Accurately map and identify rearing areas for mosquitoes, by species if possible. These would be those sites for mosquito rearing that cannot be eliminated by following preventative measures such as container emptying, proper pond maintenance, and eliminating excess standing water by using appropriate irrigation BMPs. This is important because appropriate treatment measures are contingent on the habitat (species) encountered. The following Northwest mosquito habitats and control issues have been identified in the Mosquito-borne Response Plan developed by the Department of Health (Lilja, 2002). Vectors in specific regions have not all been identified. Contact your local health department for the latest mosquito vector information.
- Demarcate no-spray zones on maps. This may include areas such as schools, hospitals, fish farms, the homes of individuals who are on chemically sensitive registers, and crops grown under a certified organic program. Other crop sites that do not have a tolerance for the mosquito control products used should also be listed. If the control entity is not a mosquito control district organized under RCW 17.28, then individual residences where the occupants do not want to be treated, should be identified as no-spray zones.

Floodwater: *Aedes vexans* and *Ochlerotatus sticticus*, which develop in large numbers along the borders of the Columbia and other rivers, create one of the most important mosquito problems in this region. The larvae hatch in the spring or early summer when the streams overflow areas such as willow and cottonwood swales where the eggs have been laid. The eggs of these species are dormant when temperatures remain below 45-50º F. Partial dormancy of the eggs may continue until sometime in June so that only some of the eggs are hatched by floods occurring in April or May. In some seasons, the larger rivers may rise, recede, and rise again to cover the same egg beds and produce an additional hatch. In other seasons, two or three successive rises may occur, each of which is higher than the last. Females that emerge in the first hatch may lay eggs that will hatch in the second or third rises of the river. Most of the eggs are laid between the 10 and 20 foot levels, and some of the eggs that are not flooded during a series of low flood crest years remain viable for as long as four years.

Large *Aedes vexans* and *Ochlerotatus sticticus* breeding areas have been managed efficiently in the past by controlling water levels above Bonneville Dam. Dikes have prevented flooding in other areas. Clearing of brush has been of value in some locations. However, control of the major section of these types of breeding areas must often be accomplished with insecticide applications.

Irrigation Water: Breeding places for several mosquito species are provided by irrigation water. *Aedes dorsalis, A. vexans, Ochlerotatus melanimon*, and *Ochlerotatus nigromaculis* are among the most important species that may develop when water is applied and stands for a week or 10 days. Other species such as *Culex tarsalis, Culiseta inornata,* and *Anopheles freeborni* may be produced if water remains for longer periods. Tremendous numbers of mosquitoes breed in many areas where uncontrolled irrigation is practiced. Applications of insecticides are effective but are not substitutes for proper grading. Elimination of standing water is effective in preventing development of mosquitoes. Application of insecticides may be necessary for breeding places that cannot be drained.

Tidal Waters: *Aedes dorsalis* is the only species that can breed in large numbers in both fresh and salt water in the Northwest. The larvae develop in some coastal areas where potholes are filled by the higher tides or where water levels fluctuate in permanent or semi-permanent pools. Leveling, drainage, or similar practices are effective in preventing breeding, but such areas must be properly maintained. Insecticide control may be necessary where these methods are inadequate or ineffective. *Ochlerotatus togoi* has also been found in coastal areas including San Juan, Island, Skagit, Kitsap, and Mason counties. Larvae of this species have been found in pools of pure seawater along rocky shorelines.

Snow Water: In many high mountain meadows and also at lower levels, mosquitoes breed in pools caused by snow melt. Development may require several weeks at higher elevations. *Aedes communis,A. cinereus, Ochlerotatus hexodontus, O. fitchii*, and O. *increpitus* are the most common species found in these locations. Usually there is only one generation per year, but the large numbers that may be produced are a severe annoyance to those who are working or seeking recreation in these areas. Elimination of breeding areas by drainage or maintenance of constant water levels is practical in some situations. Insecticide applications might have to be made by hand or by plane because of inaccessibility to heavy ground equipment.

Permanent Waters, Ponds and Artificial Containers: The mosquitoes that lay their eggs on the water are usually found where water is present continuously during the season or at least for several days. Such locations include natural permanent ponds, including still waters along the borders of lakes and rivers sheltered from wave action and currents with some degree of vegetation, log ponds, tree holes, semi-permanent ponds and wetlands of various types, and artificial containers. *Culex tarsalis, C. pipiens, C. peus, Anopheles freeborni, A. punctipennis, Culiseta incidens,* and *C. inornata* are commonly found in such places. *C. tarsalis* and *C. pipiens* develop in large numbers in log ponds. *C. pipiens* also develops in large numbers in sewer drains, catch basins, and water left in artificial containers. *Coquillettidia perturbans* are found in permanent water in wetlands, swamps, and marshes that have emergent or floating vegetation. Insecticides are often used effectively to control most of these species, except those breeding in artificial containers that can be emptied. Larvae of *C. perturbans* are difficult to control because they are attached to the roots of plants. Insecticide granules are sometimes applied, but eliminating host plants may be the most useful procedure to control this species.

Stormwater: In response to the anticipated arrival of West Nile virus in King County, King County Water and Land Resources developed recommendations for dealing with the mosquito control at County drainage facilities. The study (Whitworth, 2002) identified the four basic habitats preferred by mosquitoes, the types of mosquitoes associated with the habitat type, and the WNV vector mosquito species that prefers each habitat type. Table 1 summarizes this information.

Table 1. Disease Vector Mosquito Species Associated With Drainage Control Facilities

Habitat Type	Facility type	Vector Species
Permanent Water	Year round wet ponds Larger Regional Ponds Wet Bioswales	Anopheles punctipennis
Marshes & Wetlands	Wet Bioswales Some Regional Facilities	Aedes cinereus Coquilletidia preturbans
Temporary or Flood Water	Temporary Wet Ponds Dry Bioswales Retention/Detention Ponds Open Ditches	Aedes vexans Culiseta inornata
Artificial Containers / Tree Holes	Catch Basins Underground Tanks/Vaults Discarded containers & Tires	Ochlerotatus japonicus Culex pipiens Culex tarsalis Culiseta inornata

- Once the mosquito habitats have been mapped, confirm mosquito species associated with habitats, if possible.

Resources: Techniques and equipment for adult mosquito surveys can be found at: The Centers for Disease Control and Prevention, Guidelines for Arbovirus Surveillance in the United States, 1993, Appendix II 51-54. These guidelines are also copied in Appendix B of the Department of Health's *Mosquito-borne Disease Response Plan, November 2002 Edition*, available online at:. http://www.doh.wa.gov/ehp/ts/Zoo/WNV/WAArboviralRespPlan.pdf. Mosquito survey equipment can also be found at:

BioQuip Products
2321 Gladwick Street
Rancho Dominguez, CA 90220
USA Phone: (310) 667-8800 Fax: (310)667-8808
http://www.bioquip.com/html/aquatic_environmental.htm

- Conduct larval surveys in the area of control by dipping. The following guidance on dipping is based on an article entitled "Seven ways to a successful dipping career," published in *Wing Beats*, vol. 6(4): 23-24 by O'Malley, 1995 and reprinted in Appendix B of the Department of Health's *Mosquito-borne Disease Response Plan, November 2002 Edition,* available online at:. http://www.doh.wa.gov/ehp/ts/Zoo/WNV/WAArboviralRespPlan.pdf.

Benefits of Larval Surveillance: Larval surveys are used to determine the locations and seasons that mosquitoes use specific aquatic habitats and, when specimens are identified and counted, the information can be used to determine species composition and population densities. The information can be used to determine optimal times for application of larval control measures, including chemicals, biological controls, draining or impounding. It can also be used to help assess the effectiveness of both chemical and biological control measures. Routine larval surveillance data can be useful in interpreting adult mosquito surveillance data. For example, if larval surveys indicate 95-100 percent control by larvicides and yet the number of adults does not decline, one can suspect, in the absence of reinfestation, that an important larval concentration was missed. A system for the detection of insecticide resistance is also provided through a larval surveillance program.

Sampling Larvae: Because mosquito larvae are found in a wide variety of habitats, a number of different sampling techniques to determine their presence and density have been developed. Many, if not all, of the published methods are described in Mike Service's book, *Mosquito Ecology Field Sampling Methods* (Elsevier Applied Science, 1993). Some methods are complex mechanical devices, but the most commonly used larval collection method is the "standard dipper," a plastic or metal, white or aluminum, solid or screen-bottomed pint-to-quart-sized scoop-on-a-handle, that, along with the "sweep net," defines the Ultimate Inspector.

Dipping for mosquito larvae begins after your area has been mapped for targeted habitats with proximities that pose risk to population areas of concern. Dipping locations in control areas with multiple mosquito habitats may need to be prioritized.

The species of mosquitoes one is looking for, and the type of habitat being sampled, will, in part, determine the sampling method used. Thus, it is important that field personnel know the preferred breeding habitats and seasonal occurrence of species known or suspected to be present within an area.

Eggs are white when first deposited, becoming dark within an hour or two (Pratt, 1993, p. 13). Eggs can be laid singly on the surface of the water, in clusters called rafts that float on the surface of the water, under the water attached to roots and stems of aquatic vegetation, and singly on damp soil.

When searching for mosquito larvae, proceed slowly and carefully. Approach the area with caution to avoid disturbing larvae at the water's surface. Vibrations from heavy footsteps, casting a shadow or moving vegetation that contacts the water may be enough to cause larvae to dive to the bottom. Try to approach the water while facing the sun and with quiet, slow, soft steps. Gently move vegetation only as necessary.

Mosquito larvae of most genera, particularly the common *Culex, Aedes,* and *Anopheles*, are usually found at the water's surface and frequently next to vegetation or surface debris. In larger pools and ponds, they are usually near the margins, not in open, deep water. Dipping should be concentrated around floating debris and aquatic and emergent vegetation. If there is a strong wind, dipping should be done on the windward side of the habitat where larvae and pupae will be most heavily concentrated. Look for larvae and pupae before beginning to dip, if possible. If it is raining on the water's surface, wait until the rain stops.

Each water body may contain a number of different microhabitats which could contain different mosquito species. Microhabitats are places where a single species may congregate, as under tree roots, within clumps of emergent vegetation, under floating or overhanging vegetation and in open water. Learn to recognize different microhabitats within an area and sample as many as possible in order to obtain an accurate picture of the area's species composition.

Seven Ways to Dip: There are seven basic ways to dip for mosquito larvae. Which one or ones you use depends on the genus or genera of mosquitoes you suspect may be present, and on the habitat, microhabitat and weather conditions. The following table lists vector mosquitoes in Washington State, their habitats, ranges, and breeding sites. This table is meant to assist field identification efforts and dipping strategies. The seven dipping methods are described below the table.

Table 2. Potential Disease-Carrying Mosquitoes in Washington State

Mosquito Species	Day or Night Biter	Range	Generations per Year	Preferred Habitat	Breeding Comments
Aedes cinereus	Aggressive during day	Does not travel far from habitat	One-eggs hatch at different times	A woodland species: semi-permanent bogs & swamps, wetlands, wet bioswales & floodwaters	Hatches in the early spring. Larvae found among dense aquatic vegitation.
Aedes vexans	Day & Night	20+ miles	Many	Any temporary water body like ditches, puddles, containers, pools & floodwater.	Eggs may lie domant 3+ yrs, hatches in ditches, still water.
Anopheles punctipennis	Night	Stays near habitat.	One	Springs and creeks connected to stormwater ponds, bioswales and wetlands.	Prefers algae-laden, cool pools on edges of slow flowing rivers and streams. Has entirely dark palpi.
Coquilletidia preturbans	Night - often comes to lights	Strong fliers, enters homes and lit areas.	One, but hatchlings do not complete development until the following spring.	Permanent marshes, wetlands, temporary wet ponds, dry bioswales & open ditches.	Needs thick growth of aquatic vegetation. Remains below the water surface attached to roots and stems. Hatchlings emerge in spring.
Culex pipiens	Night	Usually migrates only short distances.	Many	Found around water with high organic content, as in catch basins & sewer effuent ponds, tree holes, artificial containers & manholes.	Proliferate in in artificial containers. Lays eggs in clusters of 50 to 400. Larval and pupal stages take 8 -10 days.
Culex tarsalis	Night	Enters buildings after dark.	Many	Any fresh water, artificial containers, & agricultural and irrigated areas	Larvae develop from spring to fall in waters w/ high organic material. Eggs laid in rafts of 100 - 150 & hatch w/in 48 hrs.
Culiseta inornata	Dawn & Dusk	Stays near habitat.	Many	Cold water - associated with glacial runoff and sunlit waters, does not like hot weather. Found at all elevations.	Breeds throughout spring and summer in cold water, females may appear during warm winter breaks. Usually feeds on livestock, not people.
Ochlerotatus japonicus	Day & Night	Not known	Many	Artificial containers, catch basins, undergound tanks and vaults & tree holes	Larvae are found in artifical containers.

*New information has come in on *Ochlerotatus canadensis* NA for first three items except that adults live for several months. Their habitat is woodland pools by melting snow or rain. They feed on a large range of mammals, birds, and reptiles.

The first and usually the best method to start with is the SHALLOW SKIM. The shallow skim consists of submerging the leading edge of the dipper, tipped about 45 degrees, about an inch below the surface of the water and quickly, but gently, moving the dipper along a straight line in open water or in water with small floating debris. End the stroke just before the dipper is filled to prevent overflowing. The shallow skim is particularly effective for *Anopheles* larvae that tend to remain at the surface longer than *Aedes* and *Culex*. *Anopheles* are usually associated with floating vegetation and debris.

The second method to try in open water, with or without floating objects, is the COMPLETE SUBMERSION. Many mosquito larvae, particularly those of the genera *Aedes* and *Psorophora*, are very active and usually dive below the surface quickly if disturbed. In this case, a quick plunge of the dipper below the surface of the water is required, bringing the dipper back up through the diving larvae. Bring the dipper up carefully to avoid losing the larvae in the overflow current.

When you need to sample at the edges of emergent vegetation, try the PARTIAL SUBMERSION technique. To do this, push the dipper, tilted at about 45 degrees, straight down adjacent to the vegetation. This causes the water around the vegetation to flow into the dipper, carrying the larvae with the flow. There is no need to move the dipper horizontally. Pull the dipper up before it is full.

In very shallow water, try the FLOW-IN method. Larvae can be collected by pushing the dipper into the substrate of the pool and letting the shallow surface water, debris and larvae flow into the dipper. Do not move the dipper horizontally.

To sample for larvae that may be under floating or emergent vegetation, use the SCRAPING technique. This method is used in habitats that contain clumps of vegetation such as tussocks of sedges, floating mats of cattails, water lettuce, or other plants that are too large to get in the dipper, or clumps of submerged vegetation such as hydrilla or bladderwort. Dip from the water in towards the vegetation and end by using the dipper to scrape up against the base or underside of the vegetation to dislodge larvae. This method is usually more effective if the bottom of the dipper is screened and it is often used to sample for *Coquillettidia* and *Mansonia* mosquitoes.

The SIMPLE SCOOP is the “dipping to get water” method that was discouraged earlier. It consists of simply scooping a dipperful of water. This is probably the most commonly used method, particularly by new inspectors, and it is often the method referred to in much of the literature as “the standard dipping procedure.” While it can be successfully used to collect *Culex* larvae, it is still not the method of choice.

The dipper can also be used as BACKGROUND. This is especially useful in woodland pools and other shallow water or when larvae are disturbed and dive to the bottom. Submerge the dipper completely to the bottom litter and slowly move it around. The darker mosquito larvae and pupae will stand out against the background of a white or aluminum dipper. Once larvae appear in the dipper, just lift it upward.

One or more of these methods, properly used, can determine the mosquito species composition of most aquatic habitats, excluding those whose openings are smaller than the dipper, such as tires, rock pools, tree holes, and tree root systems like those found in cedar and red maple swamps. In those cases, a smaller container, such as a vial, measuring spoon, or tea strainer can be used in the same seven ways as the dipper described above. Then there is the tubular dipper, or chef’s poultry baster, for those really hard to get to places such as plant axils, tree holes, and tree root holes.

Note: Locations and times of dips, and well as larvae counts, need to be recorded.

B. Monitoring for high mosquito populations and disease in *wide areas* includes the mapping and surveying strategies used for homes and offices described above, plus:

- Conduct ongoing surveillance, including studying habitats by air, aerial photographs and topographic maps, and evaluating larval populations.
- Monitor and track data from mosquito traps, biting counts, complaints, and reports from the public.
- Keep seasonal records in concurrence with weather data to predict mosquito larval occurrence and adult flights.
- Consider conducting surveillance for diseases carried by mosquitoes and harbored by birds, including crows and sentinel chicken flocks.
- Accurately map and identify rearing areas for mosquitoes. These would be those sites that cannot be eliminated by preventative measures such as emptying containers, proper pond maintenance, and eliminating excess standing water by using appropriate irrigation BMPs. These habitats can be identified by aerial photo assessments, topographic maps, and satellite imagery where available. This is important because appropriate treatment measures are contingent on the particular species that live in specific habitats.
- Agricultural site maps should include the following: Hay, pasture, circle irrigation, orchards, and rill irrigated field crops. An important land use that has caused problems to mosquito control districts in the past is flood irrigated pastures where the water stays on more than five to seven days. These areas should be mapped so that appropriate management responses may be taken.
- Demarcate no-spray zones on maps. This may include areas such as schools, hospitals, fish farms, and the homes of individuals who are on chemically sensitive registers and crops grown under a certified organic program and fish and wildlife areas sensitive to mosquito control products, pursuant to consultation with fish and wildlife management agencies. Other crop sites that do not have a tolerance for the mosquito control products used should also be listed. If the control entity is not a mosquito control district organized under RCW 17.28, then individual residences where the occupants do not want to be treated, should be identified as no-spray zones.

Note: Detailed information on mosquito surveillance is available in Washington State Department of Health's publication *Mosquito-borne Disease Response Plan,* November 2002 ed., available online at www.doh.wa.gov/ehp/ts/Zoo/WNV/WAArboviralRespPlan.pdf . Training on surveillance, trapping techniques, sampling, and vector identification techniques has been offered by Major William Sames, Chief Entomological Science Division of the U.S. Army, CHPPM-West, Fort Lewis WA. His e-mail address is william.sames@nw.amedd.army.mil and his telephone number is (253) 966-0008.

III. Establishing the Targeted Density of Mosquito Populations

Risk Assessment: Probability of outbreak in humans: Remote to low

Action threshold: The presence (positive identification) of any vector mosquitoes in the area may trigger activities to reduce their presence. Since people with compromised immune systems are likely to be the most vulnerable to mosquito-borne diseases, areas of their exposure should be a priority. General Permit Condition S4.2.C infers that the targeted density of larvae is < 1. The permit states: Pesticide applications shall not commence unless surveillance of a potential application site indicates a larva/pupa count of greater than 0.3 per dip, and the need to apply insecticides to control mosquito populations.

Rationale: Once vector mosquitoes have been positively identified in an area, control treatments are warranted. If the cost of treatments is prohibitive, every effort should be made to educate those at risk of exposure about minimizing habitat and personal protection measures.

DOH Recommended Response: Obtain surveillance and control resources to enable emergency response. Increase larval control and source reduction and public education emphasizing personal protection measures, particularly among the elderly. Enhance human surveillance and activities to further quantify epizootic activity, such as mosquito trapping and testing. Consider targeted adult mosquito control if surveillance indicates likely potential for human risk to increase.

Minimum BMP Response: Conduct outreach and education; monitor and track avian mortality, human encephalitis/meningitis, and equine surveillance in the area of control. Conduct entomologic survey (inventory habitats and map mosquito populations). Using surveillance information and input from the people in the control area, establish the targeted density of mosquito populations based on health, public safety, and funding.

A. Establishing the targeted density of mosquito populations based on health, public safety, and economic and aesthetic thresholds around *private homes or offices*:

- Individual homeowners and businesses must determine the targeted density of mosquito populations in their area, absent the existence of a mosquito control district. This determination should be based on factors of risk and cost.

- Once the targeted density has been established, continue larvae surveys to find density response to habitat minimization efforts and need for larvicide treatments.

B. Establishing the targeted density of mosquito populations based on health, public safety, and economic and aesthetic thresholds for *wide areas*:

- Mosquito control agents must consult with their sponsors to determine targeted mosquito densities. This determination should be based on factors of risk and cost.

- Once the targeted density has been established, continue larvae surveys to find density response to habitat minimization efforts and to assess the need for larvicide treatments.

IV. Mosquito treatment

Risk Assessment: Probability of outbreak in humans: Low to moderate

Action threshold: The positive identification of any vector mosquitoes in the area may trigger activities to reduce their presence. Once minimization strategies have been taken, larvae surveys (*i.e.* dipping) can indicate the effectiveness of those efforts and the need for further action. General Permit Condition S4.2.C infers that the targeted density of larvae is <1 to commence larviciding. The permit states: "Pesticide applications shall not commence unless surveillance of a potential application site indicates a larva/pupa count of greater than 0.3 per dip and the need to apply insecticides to control mosquito populations." This level is a minimum; mosquito control agents may want to set the targeted density at a higher level due to cost and risk factors.

Rationale: Once vector mosquitoes have been positively identified in an area, control treatments are warranted. If the cost of treatments is prohibitive, every effort should be made to educate those at risk of exposure about minimizing habitat and personal protection measures.

DOH Recommended Response: Obtain surveillance and control resources to enable emergency response. Increase larval control and source reduction and educate the public about personal protection measures, particularly among the elderly. Enhance human surveillance and activities to further quantify epizootic activity, such as mosquito trapping and testing. Consider targeted adult mosquito control if surveillance indicates likely potential for human risk to increase.

Minimum BMP Response: Treat mosquitoes to reduce populations below the targeted threshold using strategies that may include biological, cultural, mechanical, and chemical control methods and that must consider human health, ecological impact, feasibility, and cost effectiveness.

Conduct outreach and education; monitor and track avian mortality, human encephalitis/meningitis, and equine surveillance in the area of control. Conduct entomologic survey (inventory habitats and map mosquito populations). Using surveillance information and input from the people and/or sponsors of control in the control area, establish the targeted density of mosquito populations based on health, public safety and funding. If the targeted density level for larvae is measured after all habitat minimization efforts have been taken, prepare for targeted larvicide treatments. Prepare for an emergency response if warranted by human health impacts.

A. Use an IPM approach around private homes or offices *and* in wide areas of control:

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- Select treatments using the most effective control method or combination of methods for the particular species of mosquitoes and the breeding area found by larvae surveys.
- After attempts to minimize breeding sites have been exhausted and personal protection information has been dispersed, use biological measures whenever feasible and efficient.
- **Biological methods** may include stocking species such as the Three-Spined Stickleback (*Gasterosterous aculeatus*) in ponds or impoundments. The Three-Spined Stickleback is native to Washington State and known to be an effective predator of mosquitoes. Mud minnow, perch tadpoles, dragonfly larvae, diving beetles, back swimmers and front swimmers also prey on mosquito larvae. (More detail on these fish species is given on page 28 of the Response to Comments section of this Plan.) Guppies, goldfish, and other fish commonly sold in pet stores are exempt from permitting by Washington's Department of Fish and Wildlife (WDFW) and may be suitable for smaller ponds, horse troughs, and ornamental pools. However, before planting any of these exempt fish, please consult with WDFW. Some of these fish, such as goldfish, may have severe ecological impacts on ponds and lakes.

  The Mosquito Fish (*Gambusia affinis*) has been used for mosquito control in virtually every state because of the adult's ability to consume large amounts of mosquito larvae. These warmwater fish rarely exceed 2.5 inches and prefer shallow water. They tend to flourish in almost any environment, including well discharges, cisterns, water tanks, potholes, rain barrels, and open septic tanks. *Gambusia* have been known to dramatically reduce and even eliminate mosquito larvae. WDFW suggests that the use of *Gambusia* be integrated into an overall mosquito control plan rather than used as an exclusive solution to mosquito abatement. Permits must be obtained from WDFW for use of this non-native species as a mosquito control measure.

  WDFW has several concerns with stocking biological mosquito predators in Washington waters. Along with the introduction of non-native fish, the transfer of fish diseases from one location to another, even among native populations, can cause disease outbreaks. That is why all movement and stocking of fish requires a permit from WDFW, whether the fish are native or not. Due to the inability to test live fish without killing them, the transportation of fish from one watershed to another requires disease testing (usually on the adults at spawning, or by sacrificing a number of young fish) and verification that the remaining fish are reared on disease-free water. In addition, any non-native fish stocking currently needs to go through SEPA review prior to approval. The laws in Washington State are designed specifically to prevent this type of “Johnny Apple-seeding” from occurring. For more information, please contact your nearest Regional Office of the Department of Fish and Wildlife.

- Chemical controls can be selected by comparing targeted life stage of mosquitoes with the efficacy of the products, nontarget impacts, resistance management, and costs. Resistance management is not typically an issue for larvicides but may be considered for the use of adulticides.
- A hierarchy of preferred controls shall be developed. Pesticides that are effective in controlling the mosquito population and are the least toxic to nontarget species shall be used except in response to documented development of resistance or in a declared public health emergency. The following is the approved list of pesticide-based controls in the order of preference in which they should be considered in the mosquito control operations:
    1. Bacillus thuringiensis israelensis (Bti)
    2. Bacillus sphaericus (H-5a5b)
    3. Methoprene Granular, Liquid, Pellet, or Briquet
    4. Monomolecular Surface Films
    5. Paraffinic white mineral oil. Paraffinic white mineral oil shall not be used in waters of the state unless:
        a. The mosquito problem is declared a public health risk; or
        b. The other control agents would be or are known to be ineffective at a specific treatment site; and
        c. The waterbody is non-fish-bearing (consult Washington State Fish and Wildlife concerning fish and wildlife).

- Consult with local governments and State and Federal agencies as needed.
- Use malathion and temephos only in response to a public health concern or documented development of resistance to all less toxic control methods and in accordance with S1 of the general permit.
- Pesticide applications shall not commence unless surveillance of a potential application site indicates a larva/pupa count of greater than 0.3 per dip and the need to apply insecticides to control mosquito populations, or unless dead birds, infected horses, or adult mosquito surveys indicate the presence of vector mosquitoes when larvae counts cannot be made due to their inaccessibility. In these cases beginning control methods such as larviciding may be desirable or even necessary without the larvae dips. However, just because a dead bird is found which tests positive for WNV in an area does not mean that the vector mosquitoes are breeding in the nearest storm drain. Those in the business of controlling mosquitoes will have to know the breeding sites and species of vectors in the area to perform effective mosquito control.
- Pesticide application practices shall be followed that minimize the potential for development of pesticide resistance.
- Spills of pesticides shall be promptly reported to the appropriate local and state authorities.

Table 3. Permitted Insecticides Used For Mosquito Control

Typical Products	Active Ingredient	Label Use Rate and 2002 Cost	Application Method(s) Persistence and Comments	Human Health Impacts	Environmental Impacts	Target Pests on Label
Aquabac, Bactimos, Vectobac and Teknar	(Bti) *Bacillus thuringiensis israelensis*	0.25 to 2 pints/acre or up to 10 lbs/acre @ $24/gal. Granules $1.65/lb	Hand sprayer, ground sprayer or sprinkler cans. Effective 1 - 30 days depending on formulation. Broad spectrum, except *Coquilletidia*	Not for potable water. Minimal non-dietary and dermal risk to infants and children.[1]	Non-toxic to most nontarget species, moderately toxic to *Daphnia*[2]	Mosquito larvae
VectoLexWDG	*Bacillus sphaericus* (H-5a5b)	0.5 to 1.5 lbs/acre $4.65/lb	Granules are mixed with water and sprayed. Effective for 1-4 weeks, depending on the species of mosquito larvae, weather, water quality and exact form of the granules. Effective on *Culex spp*. Less effective against other species.	Not for potable water. Essentially nontoxic to humans[3]	No risks to wildlife, nontarget species or the environment[3]	Larvae control in water with high organic content.
Altosid liquid	Methoprene: Active ingredient is a growth hormone that does not allow the mosquito larvae to mature. Effective in controlling most mosquito species in WA	2 to 20 lbs/acre $236/gal	Use hand and ground sprayers. Effective for a few days unless specially formulated for slow release. It is not persistent because it degrades rapidly in water. The briquettes are used in areas needed for longer term residual control such as ponded areas of standing water, areas where flood waters may make it impossible to use Bti. Rates increase with deeper water. Altosid XR-G is a sand formulation, good for pastures or marshes with thick vegetation.	Not for potable water. Does not pose unreasonable risks to human health[3]	Minimal acute and chronic risk to freshwater fish, freshwater invertebrates and estuarine species. Nontarget organisms, i.e., nymph and larvae, and nontarget aquatic organisms that are highly related to mosquitoes, i.e., dragonfly, are not affected by Methoprene up to 1,000 ppb. Exposure to Methoprene will not reach levels which are toxic to aquatic non-target species either after acute or chronic exposure[4]	Horn fly, mosquito larvae, cigarette beetle, tobacco moth, sciarid fly, flea larvae, mealy bug and spider mite.
Altosid pellets	Methoprene	2.5-10 lbs/acre $28.75/lb				
Altosid XR	Methoprene	1 briquette 100-200 sq ft. $2.80 @				
Altosid briquette	Methoprene	1 briquette / 100 sq ft. $.93 @				
Altosid XR-G	Methoprene	8-10 lbs/ac $8.43/lb				

Typical Products	Active Ingredient	Label Use Rate and 2002 Cost	Application Method(s) Persistence and Comments	Human Health Impacts	Environmental Impacts	Target Pests on Label
Agnique MMF	Monomolecular surface film *Poly(oxy-1,2-ethanediyl)Alpha-isooctadecyl-hydroxy*	0.2 to 0.5 gal/acre @ $30/gal.	Sprayed by hand or ground equipment. Film remains active for 10-14 days on floodwaters, brackish waters and ponds. It is susceptible to wind breaking the surface tension and could be rendered ineffective at winds above 10 mph and in very choppy water. Adult females are killed by entrapping and drowning when they contact the surface to lay their eggs.	Okay for potable water, livestock, backyard ponds, pool covers. No risk to human health[3]	Less environmental impact than oil-kills pupa stage. Films pose minimal risks to the environment[3] Arthropods may be harmed	Larvae, pupae and midge control. Adult females.
Golden Bear Oil Bonide Oil	Petroleum distillate oils prevent the larvae from obtaining oxygen through the surface film	3 to 5 gal/acre $11/gal	Liquid formulations are sprayed by hand or ground equipment. Persists for 12 – 15 hours, then evaporates. Less expense--kills pupae stages	No risk to human health.[3]	Misapplied oils may be toxic to fish and other aquatic organisms. Label precautions reduce such risks.[3]	Larvae and pupae control
Emergency use only! Abate	Temephos	0.5 to 1.5 oz/acre $2.00/oz	Sprayed liquid. Breaks down within a few days in standing water, shallow ponds, swamps, marshes, and intertidal zones. Temephos is applied most commonly by helicopter but can be applied by backpack sprayers, fixed-wing aircraft, and right-of-way sprayers in either liquid or granular form.	Not for potable water. Poses low risk to human health. High dosages, like other OPs*, can over-stimulate the nervous system, causing nausea, dizziness, and confusion. [3]	Poses severe risk to nontarget aquatic species and the aquatic ecosystem. Very highly toxic to some aquatic invertebrates. Moderately toxic to very highly toxic to trout. 6	Mosquito larvae, midge, punkie gnat, and sandfly larvae in non-potable water.
Emergency use only! Malathion 8EC	malathion	8 oz/acre, cost NA	Labeled for use in intermittent flooded areas, stagnant water and temporary rain pools.	Harmful by swallowing, inhalation or skin contact.[8]	Toxic to fish, aquatic invertebrates, and aquatic life stages of amphibians. Highly toxic to bees.[8]	Aphids, leafhoppers, grasshoppers, spider mites, bugs, beetles, moths, worms, flies, mosquitoes and mosquito larvae

*OPs are organophophates

1. http://www.epa.gov/oppbppd1/biopesticides/factsheets/fs006476t.htm p. 3
2. http://www.epa.gov/oppbppd1/biopesticides/factsheets/fs006476t.htm p. 5
3. http://www.epa.gov/pesticides/citizens/larvicides4mosquitos.htm#microbial
4. http://www.epa.gov/pesticides/biopesticides/ingredients/index.htm#M
5. http://www.epa.gov/pesticides/citizens/malathion4mosquitos.htm p. 2
6. http://www.epa.gov/oppsrrd1/REDs/factsheets/temephosfactsheet.pdf pp. 22-23
7. http://www.epa.gov/oppsrrd1/op/malathion/summary.htm
8. http://www.epa.gov/oppsrrd1/op/malathion/summary.htm

Acquire Appropriate Management Assets

- Select appropriate mosquito management personnel: If personnel are hired directly by the public mosquito control entity, the following experiences shared by mosquito control districts should be considered:
    - Turnover can be high due to temporary nature of job, and frequent re-licensing may be needed. (All mosquito treatment personnel are required to pass the public health control exam.)
    - Some pay a fairly high salary to acquire mature workers who return every year.
    - Where a lower salary is paid, incentive programs for second year returnees (mostly college students and teachers) have been successful in getting employees to return.

Select application equipment appropriate for site size, habitats treated, and budget constraints:

- Small Size Sites–Puddle size to 10 acres: Primarily the hand method (Cyclone Spreader) application technique. Costs can vary but one eastern Washington district is able to cover 51 sites in a 23 mile stream flood plain for a total cost of $8000 per year.
- Moderate Size Sites–10 square feet to 250 acres: Primarily Truck Based Application Technique: Costs can vary from about $13 per acre and up. Some districts have variable rate tax structures such as 10 cents/ $1000 valuation for sagebrush areas, 20 cents/ $1000 valuation for wetland areas, and 30 cents/ $1000 valuation for residential areas. The total annual budget for some of the larger operations could be a million dollars or more.
- Large Size Sites–10 square feet to 250 acres: 2,500 to 10,000 acres- Primarily Aerial based Application Technique: Costs can vary from about $0.32 per acre and higher. While this is the most cost effective way to treat large acreages, the initial outlay requires an aircraft equipped for spray application. The total annual budget for a large scale operation could be a million dollars or more

Contracted Personnel and Equipment (Commercial applicators): Contracted personnel can be used for all sizes of sites. However, commercial applicators have been hired mostly for large site aerial applications. Costs can vary from one applicator to another and particularly with time of year and even time of day. Most commercial applicators have not had much experience in mosquito IPM management techniques. While they may be competent in applying a product at a particular rate, they do not always understand the behavior patterns and life cycles of the different species of mosquitoes. This ignorance can greatly degrade the effectiveness of the treatment. Therefore, the public health entity should verify that the applicators they hire have appropriate IPM training and experience in mosquito management, an appropriate public health category on their license, a positive attitude towards following the hiring entity's IPM program, and an awareness of the environmental issues surrounding mosquito abatement and their need to follow FIFRA labels and NPDES permit regulations. The hiring entities should also be aware that if their contractor violates federal regulations, such as CWA or ESA, the hiring entities may also be found liable under a third party lawsuit (as was the case in recent court case in New York over a contracted mosquito abatement program organized to combat the West Nile virus).

B. What Constitutes an Emergency

An emergency may arise when communities have not prepared for mosquito control and an outbreak occurs. In such cases, the responsible officials should immediately initiate an education and outreach program that emphasizes habitat minimization and personal protection; begin conducting larvae surveys; and secure the funding, permits and licenses needed for applying insecticides. Since insecticides can be aerially applied, the use of fogging equipment would be needed only in extremely rare cases where access is limited.

The use of any pesticide in water needs to be permitted under the Clean Water Act to protect the applicator from enforcement liability. In the case of an emergency, the use of temephos and or malathion may be authorized. Temephos and malathion are organophosphates that are conditionally allowed for mosquito control in surface waters of the state only when one of the following two conditions is met:

- As a result of consultation between the departments of Health and Ecology, in response to the development of a human health emergency as determined by the Washington State Department of Health.
- As a result of consultation between the departments of Agriculture and Ecology, and then only in response to the development of pesticide resistance within a population of mosquitoes. Monitoring of insecticide persistence and residuals shall be a condition of such approval.

C. When Adulticides Fit Into An IPM Plan

Select triggers for the use of adulticide products: Adulticiding of residential areas and upland areas where mosquitoes are migrating should be considered only when there is evidence of mosquito-borne epizootic activity at a level suggesting high risk of human infection. The following are examples of this type of evidence: high dead bird densities; high mosquito infection rates; multiple positive mosquito species including bridge vectors; horse or mammal cases indicating escalating epizootic transmission, including bridge vectors, horse or mammal cases, or a human case with evidence of epizootic activity.

Follow legal restrictions on the use of adulticide products (based on FIFRA and ESA regulations): Even when the above evidence is present, direct *application to streams and other surface waters such as wetlands, rivers, lakes, ditches, etc. is prohibited* by all adulticide labels (FIFRA) due to harm these products can do to aquatic species. Special care needs to be taken near ESA listed streams which could result in “harm” or “take” violations being assessed against the public entity if the product is sprayed into the water. The Department of Ecology, under Clean Water Act authority, prohibits the use of adulticide products on such habitats. It also prohibits such products from being directly applied to storm drains.

BMPs for adulticides:

1) Meteorological conditions:
    - Check wind speed and direction before spraying and be observant of all changes in direction and speed during the application. Use appropriate wind indicators. Gauges are highly recommended for ground applications and smoke for aerial applications.
    - Check temperature at different elevations to decide if there is an inversion.
    - Spray only when wind is away from sensitive sites.
    - Dusk is the recommended time to spray when mosquitoes are out.

2) Minimum wind conditions and temperature inversions:
    - Air inversions can go from 50 feet to 600 feet.
    - Inversions can be used to force the droplets down.
    - Spray under the inversion and only when conditions will not allow the cloud to drift into the stream.
3) Maximum wind: Do not spray in winds over 10 mph.
4) Fish-bearing stream spray buffers: Establish buffers that are outside the maximum equipment spray swath with a minimum distance of 50 feet-150 feet (depending on the skill of the operator) or follow label buffer if it is greater.

The following is a table of mosquito adulticides, all ultra low volume (ULV) organophosphates that may be used in terrestrial applications in Washington State.

Table 4. Insecticides Used for Adult Mosquito Control

Typical Products	Active Ingredient	Label Use Rate	Use	Cost	Residual Life	Comments
Biomist & Kontrol	Permethrin	ULV 4 oz/acre	Adult Control	$.24/oz	24 hours	Effective, can't use close to water.
MGK 5%, Pyrenone 25-5	Pyrethrin	ULV 1-4 oz/acre	Adult Control	$1.20/oz	1 hour	No set-backs to water. Approved for crop and pasture applications. Expensive
Scourge	Oesmethin	ULV 4 oz/acre	Adult Control	$.58/oz	1-4 hours	Has not performed well in some areas. No setbacks to water.
Fyfanon ULV	Malathion	ULV rates vary	Adult Control	$.24/oz	24 hours	Product of last resort due to impacts to nontargets.
Anvil	Sumithrin	0.0012 lb – 0.0036 lbs ai per acre	Adult Control	$.40/oz	1-4 hours	Tested and used in the NW. No water precautions.
Biomist, Kontrol, Permanone, Aqua Reslin	Permethrin	ULV rates vary	Adult control			100 ft. set-back from water
Dibrom, Trumpet	Naled	Not recommended for ground ULV use.	Adult control			Approved over crop and pasture.

Note: Organophosphate ULV products are formulated for ultra low volume applications that are highly susceptible to drift due to extremely small particle sizes.

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Response to Comments

Received During the Public Comment Period for the Best Management Practices for Mosquito Control and the Determination of Nonsignificance SEPA Checklist

This document constitutes a response to all relevant comments received during the public comment period, which included eight all-day workshops offered around the state in January 2003 where the draft was presented. It also includes a brief description of changes, other than editing changes, with reasons for the changes to the Best Management Practices for Mosquito Control and the Determination of Non-significance SEPA Checklist prepared to evaluate possible environmental impacts from the use of this plan.

Comments on the draft Best Management Practices were received between January 6 and February 10, 2003 from the following individuals and the organizations they represent.

1. David Sjogren, Fennimore Chemicals
2. Fran Krenick, Clarke Mosquito Control
3. William Leif, Snohomish County Surface Water Management
4. David Zamora, Ph.D., Northwest Mosquito and Vector Control Association
5. Allan Van Wagner, Cheminova, Inc.
6. John Bruce, Northwest Mosquito and Vector Control Association
7. Dan Mathias, City of Evertt Public Works
8. Tom Haworth, Adams County Mosquito Control District
9. James Henriksen, Benton County Mosquito Control District
10. Kevin Shoemaker, Northwest Mosquito and Vector Control Association
11. Cynthia Pratt, Washington State Department of Fish and Wildlife

Response Summary

A few updated and revised sections are a result of *informal* comments made by knowledgeable people who attended the workshops, chemical manufactures who wanted the most recent information reported on their products, and internal commenters. The majority of changes are a direct result of *formal* comments received and are reflected in this response. In particular, changes have been made to clarify Ecology's role in the development and the intended use of this Plan. Control in wetlands and other sensitive areas are clarified, as well as Ecology's authorities, especially in light of adulticide use, i.e., terrestrial applications, of insecticides that are included in this document.

Comments have been ordered to correspond to the sequential order of information presented in the BMP and SEPA documents. However, the order of the commenters is random and their comments are identified by the number assigned to them above. Ecology thanks all the contributors who made this plan possible, especially those who have been in the business of controlling mosquito populations for years who took the time to comment on the draft. This effort has been greatly improved by their contributions.

Comments on the Best Management Practices for Mosquito Control

Comments on the Introduction

1. **Commenter 2:** While mosquito control practices cannot halt the spread of West Nile Virus or other mosquito borne diseases, the goal of organized mosquito abatement is to enhance the health and quality of life through the suppression of mosquitoes and lessen the impact of mosquito related nuisance and disease. In response to West Nile Virus, health officials and mosquito control experts from around the world have participated in an annual conference to produce a document to assist municipalities, health departments and other agencies in an attempt to combat the impact of West Nile Virus. As a result, the Centers for Disease Control and Prevention have produced the document, CDC National Guidelines for Surveillance, Prevention and Control of West Nile Virus. According to these guidelines, "The principle goal is to minimize the health impact of the WN virus in humans, as well as in domestic and zoo animals."
RESPONSE: Comment noted, good information.

2. **Commenter 9:** This BMP for Mosquito Control is lacking in many different areas…. A BMP should not have negative and threatening statements made throughout its content but rather what is best for mosquito control and disease suppression. I would suggest the Department of Ecology view other BMPs produced for mosquito control before finalizing this documents and possibly try and send out another draft for review.
RESPONSE: Other BMPs were reviewed, such as the ones developed by the Washington Department of Health, a draft IPM plan by Washington State Department of Agriculture (WSDA), the IPM policy of the Northwest Mosquito and Vector Control Association, and many others available on the internet. Another draft will not be sent out due to the need to have a final plan that permittees can use by this spring. However, comments on the final draft are always welcome and will be considered as the document is updated.

3. **Commenter 9**: This BMP has several shortcomings with regards to mosquito control and how agencies should go about treating mosquito-producing areas. The sentiment when reading the introduction points towards mosquito control efforts creating a "vicious cycle" (pg 5). This is not true and should be removed. Also, stated on (pg 3) is a misunderstanding regarding mosquito control and its focus mainly on nuisance control. The very reason mosquito control districts were formed was to control disease outbreaks and many of these districts are still controlling the same disease carrying species that invoked their formation. Please revise.
RESPONSE: Cycles such as the one described on page five are potential scenarios. Mosquitoes are important pollinators as well as sources of protein for a wide variety of amphibians, birds, bats and fish. In short, they are part of what keeps our ecosystem in balance and those interrupting that balance need to be cognizant of possible consequences. Other mosquito-borne diseases such as Western equine encephalitis and St. Louis encephalitis have not been epidemic or even reported in the recent past, although they may well have provided the original impetus for the formation of the established mosquito districts in Washington State. According to the Washington Department of Health, the last reported case of a mosquito-borne disease in Washington State was Western equine encephalitis in a human in 1982 (Tom Gibbs, DOH, personal communication February 12, 2003). Any specific information about the formation of the mosquito districts you would like included in the next revision would be welcome.

4. **Commenter 10:** What is meant by the phrase "…when the effects are temporary and confined to a specific location…?"
RESPONSE: The phrase is meant to reflect consistency with Washington State water quality standards. Washington Administrative Code (WAC) 173-201A-110 establishes the criteria for the short-term

modification of the water quality standards set forth in WAC 173-201A-030 through 173-201A-030. In short, it authorizes modifications for specific water bodies on short-term bases.

5. Commenter 10: It may be a good idea to update this [human] information, especially since the number of fatalities has increased by 45 (a 20% increase), since November 26th to a total of 259 (as of 1-29-2003).
RESPONSE: Agreed. Page 3 of the Introduction has been updated with this information.

6. Commenter 11: Discussion of Purpose and Need in the Plan. While there is discussion of why we need mosquito control (from nuisance control to human health concern), there is no inclusion in the Need statement of the quantified circumstances for the proposal to be implemented. There needs to be a quantifiable reason for establishing a purpose for the proposal. For instance, what is the problem based on some measurable statistic (mosquitoes carrying the West Nile Virus have increased from 0 to 25% over the last 5 years), then the purpose will state what you are trying to achieve (eradication of West Nile Virus carrying mosquitoes). Through this approach, it will eliminate the assumption that there always must be an action taken. Potentially, there may be times or areas where control is inappropriate. In some of WDFW's wildlife areas, there may be reason for not taking action, i.e., lack of human risk, severe damage to sensitive insect populations or bats, or the numbers are minimal and predator species can keep the mosquito numbers in check.

There is some data that shows mosquito control may not work to reduce the spread of diseases such as the West Nile Virus. Dr. Mead, State -Veterinarian, handed out information at the West Nile Task Force meeting that use of mosquito control would not eliminate or control the virus. That is why it is critical that the need for the proposal be carefully identified before proceeding with alternatives that may not address your purpose.
RESPONSE: "The quantified circumstances for the proposal to be implemented" has been identified in the Goals, Logistics and Action Threshold Determinations section of the BMPs as "to achieve a level of control sufficient to maintaining an acceptable level of risk (exposure to vector and/or nuisance adult mosquitoes) with the least possible adverse impact to the environment." Ecology understands that not all communities involved in mosquito control may want to adopt this goal or will agree with the action thresholds we suggested throughout the BMP section because local conditions will vary. This is only a model plan that permittees can adopt or not. The suggested goal is reasonable, especially in light of the fact the West Nile virus has been found on both the east and west sides of Washington State.

7. Commenter 11: In the introduction, in paragraph 2, it states that mosquito abatement has expanded to a "widespread human health concern". Later in the paragraph, it states that control efforts have "no effect halting the continued spread of the virus". Then it continues to discuss reducing the risk of exposure "in some cases". There needs to be a better description of precisely where control activities are actually warranted.
RESPONSE: Action thresholds will vary from locality to locality. Exactly what warrants an action depends on mosquito survey results, proximity to population centers, the species and habitat of the mosquitoes, the weather, resources, local attitudes or tolerances of mosquitoes, and locally determined action thresholds. BMP section 3 (page 15) addresses the establishment of targeted densities for mosquito populations and states that the presence (positive identification) of any vector mosquitoes in the area may trigger activities to reduce their presence. Since people with compromised immune systems are likely to be the most vulnerable to mosquito-borne diseases, areas of their exposure should be a priority. General Permit Condition S4.2.C infers that the targeted density of larvae is < 1. The permit states that pesticide applications shall not commence unless surveillance of a potential application site indicates a larva/pupa count of greater than 0.3 per dip, (i.e., one larvae/3 dips) and the need to apply insecticides to control mosquito populations. However, when localities do not have access or control of the breeding sites that are the source of the mosquitoes in their area, another trigger may have to be identified.

Comments on the Mosquito Management Entities Section

8. Commenter 10: The phrase "…authority to spray those areas where excessive infestations are occurring…" I was unable to find the phrase "excessive infestations" in RCW 17.28. Can you direct me to where this may be found?
RESPONSE: The phrase is not a quote from the regulation. It is a paraphrase of the language in RCW 17.28.185 that addresses noncompliance by landowner with regulations, "… If the board deems that a public nuisance or threat to public health or welfare caused by the mosquito infestation is sufficiently severe, it may require ...." The language was taken from a draft plan for mosquito control by WSDA.

Comments on the Mosquito Life Cycle and Biology Section

9. Commenter 10: Can you provide more information to support the theory that is being presented. I would like specific studies that indicate that small fish (except Gambusia affins) eat mosquito larvae. I would also like information indicating what products used for mosquito control would reduce dragonfly and copepod populations, as implied in this section.
RESPONSE: The predator/prey information was given to me by personal communication with Andy Appleby, the Aquaculture Coordinator for Washington State Department of Fish and Wildlife, 12/18/02 and Randall Marshall, Whole Effluent Toxicity Coordinator for Ecology, personal communication, 2/14/03. The following is a direct quote from Mr. Marshall:

> There are three native fish in WA which would be good for mosquito control:
>
> Olympic mudminnow (*Novumbra hubbsi*) - This attractive species is unique to western Washington and considered by some to be vulnerable to extinction as a consequence of its limited distribution and our habit of draining wetlands. However, it would be superbly adapted to backyard ponds in western Washington. Its natural habitat is marshes and its food preferences would definitely include mosquito larvae. The size is just right to keep mosquito larvae near the top of the food preference list throughout its life. The public would love this fish and WDFW scientists would enjoy the opportunity to learn more about it.
>
> Redside shiner (*Richardsonius balteatus*) - This native fish is a good alternative to the mudminnow. It would live anywhere in the state and can tolerate moderate currents. It has been found in irrigation ditches as well as ponds. Its size and food preferences would make it a good predator of mosquito larvae.
>
> Three-spine stickleback (*Gasterosteus aculeatus*) - Sticklebacks have been used in mosquito control and can live in any water regardless of salinity. Some backyard ponds are kept brackish for koi (fancy carp).
>
> These three native fish in combination would make for a good selection. The mudminnow should adapt very well to shallow, muddy, weedy backyard ponds in western Washington but are unlikely to be successfully introduced outside of their natural range. Mudminnows might be more tolerant of low dissolved oxygen than the others (mosquito larvae breathe air). The shiner would be the most adaptable to ponds and ditches in eastern Washington. The stickleback has perhaps the best osmoregulatory ability of any fish and would live in freshwater, saltwater, or mildly polluted water (especially metals).
>
> Stickleback culture is already worked out. Redside shiner culture may not be worked out but other shiners are cultured and the techniques would tend to be similar. The Olympic mudminnow is so unique that culture technique is difficult to predict, but knowing more about this fish is a good idea all on its own.

As to possible impacts of control products to nontargets, please review the following web download:

1. *Environmental Toxicology and Chemistry:* Vol. 19, No. 3, pp. 678–684. EFFECTS OF THE MOSQUITO LARVICIDES TEMEPHOS AND METHOPRENE ON INSECT POPULATIONS IN EXPERIMENTAL PONDS, by

Alfred E. Pinkney,[a] Peter C. McGowan,[a] Daniel R. Murphy,[a] T. Peter Lowe,[b] Donald W. Sparling,[b] and Leonard C. Ferrington[c]

[a]*U.S. Fish and Wildlife Service, Chesapeake Bay Field Office, 177 Admiral Cochrane Drive, Annapolis, Maryland 21401*

[b]*U.S. Geological Survey, Patuxent Wildlife Research Center, 11510 American Holly Drive, Laurel, Maryland 20708*

[c]*Department of Entomology, University of Kansas, 2041 Constant Avenue, Lawrence, Kansas 66047 USA*

(*Received* 10 *January* 1999; *Accepted* 25 *June* 1999)

Abstract—The nontarget effects of Abate® 4E (44.6% temephos) at 0.054 kg of active ingredient (a.i.) per 1 ha and of Altosid® Liquid Larvicide (5% methoprene) at 0.011 kg a.i./ha were investigated in 18 experimental ponds (average area, 202 m^2; maximum depth, 0.7 m) at Patuxent Wildlife Research Center, Laurel, Maryland, USA. Ponds were sprayed three times at 3-week intervals. Six ponds were sprayed with Abate, six with Altosid, and six with distilled water. Two insect-emergence traps per pond collected for 7 d and were then harvested 1 d before each spray and 13 to 14 days afterward. A repeated measures analysis of variance (ANOVA) revealed significant reductions in Shannon diversity, equitability, and numbers of individuals, species, and families in the Abate ponds relative to controls. Significant reductions also occurred in Ephemeroptera, Odonata, Diptera, Chironomidae, and *Chaoborus* sp. Hester-Dendy samplers were installed before spray one and harvested 16 d after spray three. Based on one-way ANOVA, Shannon diversity, equitability, and number of Ephemeroptera and Chironomidae were significantly reduced in the Abate ponds. Emergence data indicate only isolated cases with significant reductions in the Altosid ponds relative to controls, and the Hester-Dendy data indicate no significant differences between the Altosid and control ponds.

2. *Environmental Toxicology and Chemistry:* Vol. 19, No. 8, pp. 2107–2113. EFFECTS OF ENDOCRINE-ACTIVE CHEMICALS ON THE DEVELOPMENT OF SEX CHARACTERISTICS OF *DAPHNIA MAGNA* by Allen W. Olmstead,[a] and Gerald A. LeBlanc[a]

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(*Received* 23 *August* 1999; *Accepted* 11 *January* 2000)

Abstract—Standard reproductive assays with daphnids involve parthenogenetically reproducing females and exclude the assessment of effects on sexual reproduction. The goals of this study were to characterize sexual differentiation of male and female daphnids (*Daphnia magna*) and to evaluate whether exposure to putative endocrine-disrupting chemicals may perturb the development of sex characteristics. Anatomical sex differences that developed during maturation in males included elongated first antennae and morphologic alterations in the head capsule and carapace edge. Reproductive maturation in females was associated with the development of a brood chamber and abdominal process. Alterations in the growth rates of the first antennae of males and the abdominal process of females were used to evaluate the effects of chemical exposure on the development of these sex characteristics during maturation. Exposure of female daphnids to the nonsteroidal vertebrate estrogen diethylstilbesterol and the insect juvenile hormone analog methoprene at concentrations as low as 3.0 and 0.080 M, respectively, stimulated development of the abdominal process. Exposure of males to the steroidal vertebrate androgen androstenedione (6.0 M) stimulated development of the first antennae. These results demonstrate that the development of secondary sex characteristics in daphnids can be altered by chemical exposure.

3. *Environmental Toxicology and Chemistry:* Vol. 16, No. 5, pp. 1014–1019. DO MOSQUITO CONTROL TREATMENTS OF WETLANDS AFFECT RED-WINGED BLACKBIRD (*AGELAIUS PHOENICEUS*) GROWTH, REPRODUCTION, OR BEHAVIOR? By JoAnn M. Hanowski,[a] Gerald J. Niemi,[a] Ann R. Lima,[a] and Ronald R. Regal[b]

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(*Received* 30 *August* 1996; *Accepted* 8 *October* 1996)

Abstract—We found no convincing evidence that reproduction, growth, or foraging behavior of red-winged blackbirds (*Agelaius phoeniceus*) were negatively impacted by treatments of wetlands with either *Bacillus thuringiensis israelensis* (*Bti,* applied as Vectobac-G granules) or methoprene (applied as Altosid sand granules). Most red-winged blackbird parameters examined varied annually and some differences were found before treatments began. In all cases, differences found before treatments were either found again during the treatment years or no patterns existed to suggest impacts of mosquito control treatments. Only 1 of the 22 variables examined indicated a significant difference between a treatment group and the controls; males in *Bti*-treated sites were larger than males in control sites during the treatment years. Clutch size indicated a significant treatment-by-year interaction and was higher in control areas as compared with *Bti*-treated areas in 3 of the 6 years of study; 2 years occurred before any treatments were applied. Data from benthic aquatic insect studies showed that aquatic insects were depressed in wetlands treated with both methoprene and *Bti* in July and August. However, it is unlikely that food available to avian species in these wetlands was lower during the breeding season (May and June). Other portions of the avian life cycle that may be affected include the dispersal of young birds within or to these sites and individuals that use wetlands during migration. Impacts on these aspects of the avian community and landscape-level effects of treatments were not addressed.

4. *Environmental Toxicology and Chemistry:* Vol. 18, No. 3, pp. 549–559. ECOLOGICAL EFFECTS OF MOSQUITO CONTROL ON ZOOPLANKTON, INSECTS, AND BIRDS by Gerald J. Niemi,[a, b] Anne E. Hershey,[b] Lyle Shannon,[b] JoAnn M. Hanowski,[a] Ann Lima,[a] Richard P. Axler,[a] and Ronald R. Regal[c]

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(*Received* 2 *May* 1997; *Accepted* 25 *June* 1998)

Abstract—We completed an integrated, 6-year study on the potential ecological effects of two mosquito control agents, methoprene (applied as Altosid™ sand granules) and *Bacillus thuringiensis* var. *israelensis* (*Bti,* applied as Vectobac-G™ granules), on zooplankton, insects, and breeding birds in wetlands of central Minnesota, USA, from 1988 to 1993. The study was a before-and-after design with pretreatment (1988–1990) and post treatment (1991–1993) of 27 wetlands. Study sites were randomly selected and placed within one of three groups of sites, nine control, nine *Bti*-treated, and nine methoprene-treated. Selected populations of zooplankton, insects, and breeding birds were sampled within each of these wetlands. Insect densities were reduced by 57 to 83% and biomass was reduced by 50 to 83% in the second (1992) and third (1993) years of treatment. No negative effects on zooplankton or breeding birds could be attributed to treatment or changes to insect communities. Many factors may explain the lack of effects on breeding birds including, reductions in insects occurred after the nesting season was over, nest loss rates due to predation were very high (70%) and may have been a greater limiting factor to birds than mosquito control, and the density of breeding birds may be below carrying capacities, especially because not all wetlands in the landscape were treated and sufficient food may have been available. It is unclear what the long-term consequences of insect reductions mean to wetland health. The lack of close coupling between zooplankton, insects, and breeding birds probably reflects the ecological complexity of these wetlands such as the presence of other limiting factors on population distribution and abundance. Although the study period was relatively long (3 years of treatment) compared with most ecological studies of pesticides, it may not have been long enough to fully predict the effects of decades of continued mosquito control.

5. *Environmental Toxicology and Chemistry:* Vol. 19, No. 12, pp. 2923–2928. USE OF FRESHWATER ROTIFER *BRACHIONUS CALYCIFLORUS* IN SCREENING ASSAY FOR POTENTIAL ENDOCRINE DISRUPTORS by Benjamin L. Preston,[a] Terry W. Snell,[a] Tish L. Robertson,[a] and Brian J. Dingmann[a]

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(*Received* 17 *September* 1999; *Accepted* 17 *April* 2000)

Abstract—Reports of the effects of endocrine disruptors on aquatic invertebrates are becoming increasingly common. However, little is known about the endocrine systems of most aquatic invertebrates, limiting the development of assays based on endocrine mechanisms. As a result, endocrine disruption is often inferred through the effects caused by the

chemical of interest, making it difficult to rule out other mechanisms of toxicity. To be a good candidate for an endocrine disruptor, effects should be observed in processes known to be under endocrine control, at life stages where endocrine signals are known to be active, and at concentrations below acute and chronic toxic effects. We developed a 96-h reproductive assay using the freshwater rotifer *Brachionus calyciflorus* to screen for potential endocrine disruptors and examined cadmium, chlorpyrifos, naphthol, pentachlorophenol, estradiol, methoprene, precocene, nonylphenol, flutamide, and testosterone for effects on asexual and sexual reproduction. Flutamide, testosterone, and nonylphenol inhibited fertilization of sexual females at concentrations of 1, 10, and 50 g/L, respectively. The fertilization no-observable-effect concentrations (NOECs) for these compounds were 5 to 200 times lower than previously described reproduction NOECs for *B. calyciflorus.* Sexual reproduction was inhibited with no effects on asexual reproduction, increasing the likelihood that these specific reproductive effects occurred through an endocrine mechanism. Rotifer reproduction assays may be a useful, rapid, and inexpensive method for screening compounds suspected to have endocrine disrupting activity in aquatic invertebrates.

6. *Environmental Toxicology and Chemistry:* Vol. 20, No. 3, pp. 582–588. METHOPRENE AND 20-OH-ECDYSONE AFFECT MALE PRODUCTION IN *DAPHNIA PULEX* by Jane K. Peterson,[a] Donna R. Kashian,[a] and Stanley I. Dodson[a]

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(*Received* 18 *January* 2000; *Accepted* 16 *July* 2000)

Abstract—Exposure of *Daphnia pulex* to the insecticide and juvenile hormone-mimic methoprene resulted in a decrease in the incidence of all-male broods and an increase in the incidence of all-female broods compared with controls. These effects were observed at nominal concentrations of 10 and 100 g/L, within the upper range of concentrations at which methoprene is applied in the environment. Because methoprene has been found to bind to the mammalian retinoid X receptor, we also tested the effects of retinoic acid on *Daphnia* reproduction. Neither 9-*cis*-retinoic acid nor all-*trans*-retinoic acid had any observable effect. Because juvenile hormone and ecdysteroids interact in many insect systems, we also exposed *Daphnia* to 20-OH-ecdysone. Exposure to the crustacean hormone 20-OH-ecdysone at levels of 1 and 10 g/L resulted in an increase in all-male broods and a decrease in all-female broods, but 100 g/L 20-OH-ecdysone resulted in a decrease in all-male broods and an increase in all-female broods. Our results suggest that juvenile hormone and ecdysteroids might play a role in the *Daphnia* sex determination system.

7. *Environmental Toxicology and Chemistry:* Vol. 21, No. 8, pp. 1664–1672. RESPONSES OF SONGBIRDS TO AERIAL SPRAYING OF THE MICROBIAL INSECTICIDE *BACILLUS THURINGIENSIS* VAR. *KURSTAKI* (FORAY 48B®) ON VANCOUVER ISLAND, BRITISH COLUMBIA, CANADA by Lennart Sopuck,[a] Kristiina Ovaska,[b] and Bruce Whittington[c]

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(*Received* 26 *September* 2001; *Accepted* 14 *January* 2002)

Abstract—Use of bacterial insecticides containing *Bacillus thuringiensis* var. *kurstaki* (Btk) is gaining popularity as an environmentally safe control measure against lepidopteran pests, but indirect effects on nontarget organisms through reduced prey base have received little attention. Aerial spraying of Btk (Foray 48B®) over a 12,803-ha area on southeastern Vancouver Island (BC, Canada) in May to June 1999 as part of a gypsy moth (*Lymantria dispar*) control program provided us with an opportunity to examine the responses of songbirds to spray application. To obtain an estimate of species richness and relative abundance, we conducted standard songbird point-count surveys in Garry oak (*Quercus garryana*)–dominated habitats in Btk-sprayed and unsprayed areas in April to June 1999 and, one year after

spraying, in 2000. These surveys revealed no patterns consistent with adverse effects of spraying on the relative abundance of adult birds or singing males for any of the species, whether examined individually or when combined into foraging guilds. An exception was the spotted towhee (*Pipilo maculatus*), which in 1999, but not in 2000, occurred at significantly lower numbers in sprayed plots after Btk treatment. Intensive searches of plots in sprayed and unsprayed areas revealed no differences in the numbers of songbird broods between the two areas for any of the species examined.

Comments on the IPM – Based Best Management Practices Section

10. Commenter 2: IPM is a planned and preventative approach to pest management, which considers a number of options, including chemical and nonchemical control for managing pests. The Washington State Legislature has provided a legal definition of integrated pest management in RCW 17.15.010, which states: "'Integrated pest management' means a coordinated decision-making and action process that uses the most appropriate pest control methods and strategy in an environmentally and economically sound manner to meet the agency programmatic pest management objectives." Components within an IPM program should include: Surveillance, Source Reduction, Chemical Control, Biological Control, Resistance Management, Continuing Education, Public Education and Legislation.
RESPONSE: This BMP plan seems to be missing the Resistance Management and Legislation components listed above. Resistance management was added to the BMP section of the plan (page 19), but legislation will not be included. Communities and others who feel legislative support or regulation is needed in the area of mosquito control are encouraged to contact their respective Representatives.

11. Commenter 10: In RCW 17.15.010(1)(c) it reads, "Establishing the density of the pest population, *that may be set at zero,* that can be tolerated or correlated with a damage level sufficient to warrant treatment of the problem based on health, public safety, economic, or aesthetic thresholds;" (Italics were added) Can you explain why you chose to leave out the phrase "may be set at zero?" The way this section is written in the BMP draft seems to imply that you cannot have a threshold of zero.
RESPONSE: As noted above, General Permit Condition S4.2.C sets the targeted density of larvae at <1. The permit states that pesticide applications *shall not* commence unless surveillance of a potential application site indicates a larva/pupa count of greater than 0.3 per dip, (i.e., one larvae/3 dips). The permit was available for draft review for a minimum of 30 days. Your comment on the density decision needed to be made during that time for Ecology's consideration. When the permit is renewed it will go though another draft review period and your comments will be welcome on the permit at that time.

Comments on the Goals, Logistics & Action Threshold Determinations

12. Commenter 2: The fact that it may require a minimum of 38 days to obtain a license and permit to undertake mosquito control activities would likely inhibit a community to address an emergency health situation due to West Nile Virus. The history of WNV in other communities has demonstrated that once the virus has been identified, human cases soon follow, in most cases, much sooner than 38 days. Consideration must be given in the permit process for emergency situations. Education of the public in the areas of mosquito habitat reduction and personal protection in and of itself is not protecting the public from disease as is implied in the draft document. CDC National guidelines for surveillance, prevention and control of West Nile Virus states, "As evidence of sustained or intensified virus transmission in an area increases, emergency preparations should be commenced and implemented as needed".[1]
[1] http://www.cdc.gov/ncidod/dvbid/westnile/resources/wnv-guidelines-apr-2001.pdf
RESPONSE: The permit is not meant to preclude actions that may be needed in the event of an emergency. A community may apply for permit coverage now and have that in place before mosquito season arrives. This would be especially advisable for communities that have not adopted a BMP plan, for as you know, effective mosquito control entails much more than spraying insecticides on mosquitoes. In addition, there are many complicating factors to consider in what is essentially a risk management decision.

1) Ecology does not have the authority to waive the Clean Water Act requirement for permit coverage of discharges of pollutants into surface waters (neither does EPA). Neither does Ecology have the authority to intercede if a third party lawsuit is filed. The liability under a third party lawsuit which can be filled by any citizen can be as high as $25,000 per violation.
2) Education is only one part, a preliminary and necessary part, of an integrated pest management approach to control mosquitoes.
3) Larvicides cannot be effectively applied with out knowing the breeding site or, if that is not available, the place of entry into the control area of the mosquitoes presenting the risk, the species and stage of development that they are in, and the desired density. Control entities must also have the proper equipment and expertise to make the applications. If entities desiring to control mosquitoes apply larvicides to water without the proper preparation, licenses, and permits, they may be spending a lot of money, putting themselves in a liable situation, and still have no impact on mosquito densities.
4) If entities want to apply adulticides not labeled for use in water to terrestrial sites, they do not need to have permit coverage.
5) The need for planning ahead of the mosquito season was the main reason WSDA, DOH and Ecology collaborated on presenting the West Nile virus workshops statewide in January, attended by nearly 500 people statewide. We have been working with mosquito control entities, local governments, and licensed applicators to help them prepare for the spread of the West Nile virus in their communities this summer. We hope to avert the emergency situations you are talking about.
6) Communities that want to apply larvicides to water that are caught in an emergency situation without permit coverage should apply for coverage along with their request to be considered for emergency status by the local health department. That way they will be covered in the event a Notice of Intent is filed under the Clean Water Act.

13. Commenter 10: Where does DOE get its authority to design a BMP for mosquito control entities?
RESPONSE: The Washington State Department of Ecology is authorized under Revised Code of Washington (RCW) 90.48, the Water Pollution Control law.

> RCW 90.48.030, Jurisdiction of department.
> The department shall have the jurisdiction to control and prevent the pollution of streams, lakes, rivers, ponds, inland waters, salt waters, water courses, and other surface and underground waters of the state of Washington.

Ecology did not promulgate the BMP Plan as a rule. We developed it to fulfill our own permit requirement in the NPDES general mosquito control permit as an aid to new permittees who were unfamiliar with mosquito control techniques and integrated pest management. The BMP Plan is the product of WSDA, DOH, WDFW and Ecology collaboration.

14. Commenter 10: Where does DOE get its authority to deny the BMP/IPM submitted by mosquito control entities? (Based on the statement "those who wish to develop their own BMP/IPM plan must have their individual plans approved by Ecology before they can apply pesticides to surface waters in Washington State.")
RESPONSE: Ecology's statutory authority is found in RCW 90.48 Water Pollution Control law.

15. Commenter 10: What agency or individual(s) will be conducting the reviews for BMPs/IPMs that are submitted by entities?
RESPONSE: Ecology staff responsible for managing the mosquito control permit.

16. Commenter 11: Under the IPM discussion on page 5, there needs to be added a statement that control for West Nile Virus (WNV) be undertaken only for those situations where mosquitoes capable of transmitting

the virus are present. Is every species of mosquito is capable of successfully transmitting WNV? Ecology's plan should target only real, and not perceived, threats.
RESPONSE: Mosquito control is authorized under Ecology's general permit whether the West Nile virus is present in Washington or not. The permit does not distinguish species exempt from control. Only eight or nine species found in Washington are capable of spreading the West Nile virus (see Table 2 on page 13).

Comments on the Mosquito Control Section

17. Commenter 2: In contradiction to the draft document, healthy wetlands do provide excellent mosquito breeding habitats for a variety of disease vector mosquitoes such as *Cq. peturbans, Culiseta spp., Anopheles spp., Culex tarsali*s, etc. to name a few. Examples of such habitats include, but are not exclusive to, cattail marshes, salt marshes, hardwood swamps, woodland pools, etc. A well established method of wetland management for the purpose of mosquito control is the Open Marsh Water Management program successfully and effectively implemented in the Northeast.[2]

BMP minimum response does not consider DOH and or CDC guidelines, which consider targeted adult mosquito control by stating, "…adulticiding based on surveillance is an extremely important part of any integrated mosquito management program." An important component of the CDC guidelines is to include monitoring for disease as well as monitoring mosquito populations. The draft document is biased to restricting mosquito control activities to education, surveillance and source reduction and little or no emphasis on mosquito control or disease surveillance. The BMP should consider the CDC guidelines for response directions.

Per the BMP document, once vector mosquitoes have been identified in an area, control treatments are warranted, however, the recommended control methods are exclusive to the use of fish to control mosquito larvae populations. Although certain fish species are a viable method for larval control, there are many instances in which they would not be effective. Introducing fish into habitats that are breeding mosquitoes heavily but are not suitable for fish, such as temporary woodland pools, temporary drainage areas, artificial containers, tree holes, catch basins, etc. would not effectively reduce mosquito breeding. Since the transportation and stocking of non-native fish species to Washington waters requires additional permitting, it would be prohibitive for a district or community to pursue this approach for widespread mosquito control.
[2] http://www.nmca.org/Nmca95-10.htm
RESPONSE: On pages 10 and 13 as well as in numerous other places, the draft document identified mosquito species associated with wetlands.

Delaware's Open March Water Management method can be used only in tidal marshes wherever that method is approved for use. It was developed to remedy the damage caused by extensive ditching of salt marshes. It does not, and never should be applied, to freshwater marshes. The excavation is to provide habitat for small salt marsh fishes that eat the larvae of salt marsh mosquitoes during high tide. Providing this habitat proved to be very effective for controlling larvae. Our salt marshes in the Northwest are different; it is not known how effective the method would be here and it has not been approved for use.

The draft BMPs were largely based on DOH and CDC guidelines except for targeting adult mosquito control by use of insecticides labeled only for terrestrial use because Ecology does not regulate the use of those products. However, Ecology recognizes that you are correct in stating, "…adulticiding based on surveillance is an extremely important part of any integrated mosquito management program." While Ecology wants to be clear that we have no jurisdiction over the use of products applied terrestrially, we do recognize that often mosquito breeding sites are outside of the control agent's jurisdiction or they can be either too large or too inaccessible to treat with larvicides. In these cases adulticiding may well be an important tool in a mosquito control program. The BMPs have been revised to clarify this important control option.

Ecology also agrees that monitoring for disease is an important component of a mosquito control management plan and has added this step to the BMPs.

18. Commenter 3: The introduction of perch and gambusia as mosquito-eating fish species, as described in Sections 1A, !B, and 4A, should not be allowed for stormwater facilities such as detention ponds. The plan should be more explicit in distinguishing between water features with no surface outlet (such as watering troughs in arid regions) and those that could release nonnative fish to receiving waters. The release of such fish has caused significant environmental harm in many parts of the world, and may have actually increased mosquito populations by eradicating other species that feed on mosquitoes.
RESPONSE: Agreed. Clarification that these options are suitable only for waters with no surface outlet without prior approval from WDFW has been made to the BMPs.

19. Commenter 10: Bullet #11: were studies provided for review by DOE on these statements?
RESPONSE: Statements were received from Andy Appleby, the Aquaculture Coordinator for Washington State Department of Fish and Wildlife, 12/18/02 and Randall Marshall, Whole Effluent Toxicity Coordinator for Ecology, personal communication, 2/14/03.

20. Commenter 10: Last paragraph, second and third sentences: Do you have studies available to back up the claim that "healthy wetlands" provide minimal habitat for mosquitoes (even less than a drained habitat)? Or studies to support the statement that "…amphibians, bats and birds, feed heavily on any mosquitoes present."
RESPONSE: Wetlands will provide a breeding site for many species of mosquitoes as well as many predator species such as frogs, birds, and bats that tend to keep the mosquito populations in "balance." Nature's balance, however, does not usually result in the eradication of a species within an ecological system such as a wetland or even keep mosquito populations down to a level that many people would consider "effective control."

We agree that the statement "frogs, birds, and bats feed *heavily* on mosquitoes" is a common misconception. Most predation on mosquitoes occurs when they are larvae, so the best mosquito control is to target the larvae, either by fostering their predators (amphibian larvae, aquatic salamanders, small fish) or by selective larvicides such as BTI. Wetland literature suggests that dragonflies are probably the only significant predator on adult mosquitoes. Mosquito "outbreaks" occur in destabilized wetland and stream ecosystems where the predators of the larvae are excluded. It is the wetlands we have changed and tampered with that tend to have the worse mosquito problems (Tom Hruby, Ecology Wetland Specialist, personal communication 2/26/03).

21. Commenter 10: Section A, paragraph 1, Bullet #3: What information was used to determine that guppies, goldfish and other fish commonly sold in pet stores may be viable options for mosquito control in small scale situations?
RESPONSE: Statements were received from: Andy Appleby, the Aquaculture Coordinator for Washington State Department of Fish and Wildlife, 12/18/02 and Randall Marshall, Whole Effluent Toxicity Coordinator for Ecology, personal communication, 2/14/03.

22. Commenter 11: Under page 7, A.: Mudminnows may not be allowed to be used because they may be outside their native range. We do not want to arbitrarily increase the range of the Olympic mudminnow a state "sensitive" species without a management plan for the species. There is no plan at this time, but it would be very unlikely that WDFW would recommend the introduction of Olympic mudminnows for mosquito control. They probably are not that good at controlling mosquitoes. Mosquitoes like open water and mudminnows very seldom leave the shelter of thick aquatic vegetation. In addition, WDFW does not want to arbitrarily increase the range of yellow perch, which frequently are a nuisance exotic species that prey upon native species. Sticklebacks are a possibility but perch, or any non-native fish, should not be used. Our agency, particularly those that manage the stocking of fish, should be allowed to closely review the whole concept of biological control using fish.
RESPONSE: Since mudminnows are a native species, their use does not have to be permitted by Washington State Department of Fish and Wildlife (WDFW), although checking with WDFW before

introducing any new species to a water system is advised and using non-native species does need to be permitted by WDFW. In addition, not all species of mosquitoes breed in open water. Larvae can be found floating amongst emergent vegetation as well as completely submerged and attached to the roots and stems of cattails and other emergent wetland plants.

23. Commenter 11: One of the potential control measures not mentioned is the use of installation of bird nest boxes and bat houses. This potentially may be better as a biological control measure than to plant fish.
RESPONSE: While many species of birds and bats eat mosquitoes, they usually do not eat enough to constitute a reliable control measure.

24. Commenter 11: Page 8 again has the fish stocking option that needs much more thought. What appears apparent overall, is that the plan does not have sufficient discussion of options and risks.
RESPONSE: We agree that the plan could use more discussion of options and risks. More discussion in these areas will be developed as the plan is updated and amended.

25. Commenter 11: One BMP mentioned to reduce human risk is to avoid areas with known concentrations of vectors. This BMP seems a reasonable option that should be one of the primary ways to control mosquito-carrying diseases.
RESPONSE: Agreed.

26. Commenter 3: Section 4A should state that the choice of treatments should be based on both the effectiveness of the control agent and the relative ecological effects, not just the effectiveness.

Section 4A should include a hierarchy of preferred controls based on the relative effects on nontarget species. This would aid mosquito control staff in selecting the proper control based on a balance between effectiveness and collateral ecological effects.
RESPONSE: Section 4A has been amended to include ecological considerations, and the permit does outline the approved list of pesticide-based controls in the order of preference in which they should be considered in the mosquito control plan (this order was followed in the suggested BMPs). Creating a prescriptive hierarchy of preferred controls is challenging because what may be an appropriate hierarchy for a wetland may not work for an irrigation system, or a snow melt area, or an estuary, or for an area where the breeding site is inaccessible. Each of these types of habitats may need a hierarchy developed for them. A decision tree has been added, however, for each of these specific sites as suggested in Condition S4.A of the permit.

27. Commenter 9: Some of the opinions expressed in this BMP either need to be taken out or backed by scientific study and not hearsay. I would like to see scientific information backing statements on (pg 9) with regards to Wetlands and Greenbelts? There also needs to be updated and accurate data along with scientific studies for the "Permitted Insecticides Used For Mosquito Control." section. This section has numerous mistakes that need to be addressed before finalization.
RESPONSE: Comment noted.

28. Commenter 11: The more plants that are growing on the water surface, the fewer mosquitoes. This should also be a BMP, where appropriate. For instance, the first fall at the Dungeness wetland, WDFW staff had lots of mosquito larvae. That was the last time they were seen in such abundance. Shortly, plants grew, birds fed on the mosquito larvae, other insects replaced the larvae and the wetland functioned without pesticide use.
RESPONSE: Comment noted.

29. Commenter 7: On page 15 of the BMPs, it is stated that larviciding of surface waters cannot commence until the threshold level of mosquito larvae density is exceeded. According to Tom Gibbs, Department of Health (at 1/10/03 mosquito control training in Mt. Vernon), there is only an approximately 2 week lag time between discovery of a WNV vector and the first human WNV case in the vicinity. Given that it is a foregone conclusion that nearly every stormwater pond in western Washington will have WNV vectors during the mosquito breeding season and that in most communities it will take more than two weeks to complete a round of stormwater pond larviciding (approximately one month for the City of Everett), it is inappropriate to require permittees to forego larviciding until it is documented that an imminent problem exists.

Furthermore, I recently received an e-mail from John Marzluff, associate Wildlife Sciences professor at the U of W. He states that crows can fly 30 kM in one day. Therefore, I recommend that the BMPs allow application of larvicides if monitoring shows larva/pupae count greater than 0.3 per dip or if a dead bird that tests positive for WNV is found within 18 miles of the potential application site.

RESPONSE: Your point is well taken. The threshold level of mosquito density was set to prevent superfluous applications of larvicides, and dipping for mosquito larvae was the recommended method for determining a threshold presence. However, if dead birds, infected horses, or adult mosquito surveys indicate the presence of vector mosquitoes when larvae counts cannot be made due to their inaccessibility, then beginning control methods such as larviciding may be desirable or even necessary without the larvae dips. On the other hand, just because a dead bird is found which tests positive for WNV in an area does not mean that the vector mosquitoes are breeding in the nearest storm drain. Those in the business of controlling mosquitoes will have to know the breeding sites and species of vectors in the area to perform effective mosquito control. The permit will be slightly modified to allow for these other indicators to trigger larviciding when mosquito breeding sites are inaccessible or not practical to monitor.

30. Commenter 8: Storm drains will produce *Culex pipiens*. They are of concern to be a carrier of West Nile Virus. Other states especially in the south adulticide storm drains to help control the mosquitoes that the larvacides miss. When you are in fact concerned with the health of people, you try to stop the spread of any disease especially when you can locate the source. That is good stewardship.

RESPONSE: Comment noted. A word of caution, storm drains are considered surface waters, and many adulticides are not labeled for use in water.

31. Commenter 1: Page 18 Table 3 “Permitted Insecticides Used For Mosquito Control” Insert a cost for Bti Liquid of $24.00/gl Change cost of Bti Granules to $1.65/lb ($1.45 is for large volume users)
Target pests on label for Altosid should be only mosquito larvae. Highly acutely toxic to most invertebrates for Altosid is not accurate at label rates for mosquitoes. Agnique MMF pricing should read $30.00 per gallon, not $200/gl

RESPONSE: Price changes noted and the BMP amended. Thank you. We also agree with your comment regarding the toxicity of methoprene and the potential effects on nontarget species. The information used in the draft BMP is from EPA’s website which referenced EPA’s 1991 Registration Eligibility Document (RED). There is now an updated 2001 RED available online at the EPA's website. The old RED contains information that was current at the time it was published; however, at that time there was incomplete information or data that was in process. Some of the statements were made due to a lack of studies or studies in progress. These studies have since been completed and the EPA has released the updated RED sheet. Specifically the updated RED states:

> <u>Environmental Fate</u>
>
> All the environmental fate data requirements for Methoprene have been satisfied. The available information indicates that Methoprene will not result in unreasonable adverse effects on the environment since Methoprene degrades rapidly in sunlight[27], both in water and on inert surfaces. Methoprene is also metabolized rapidly in soil and does not leach[29]. Thus, Methoprene is not expected to persist in soil or contaminate ground water.
>
> <u>Ecological effects</u>
>
> Methoprene has been shown to be practically non-toxic to terrestrial species including mallard ducks and quail- and Methoprene had no effect on mallard[33] or quail[34] reproduction.

Ecological effects studies on aquatic species either on file with the Agency or submitted by the registrant between 1993 and 1996, indicate minimal acute and chronic risk to freshwater fish[35,36,37], freshwater invertebrates and estuarine species [40,41,42,43] from exposure to Methoprene mosquito products.

Extensive research has addressed the effects of Methoprene on nontarget aquatic and terrestrial organisms. Acute, short-term and subchronic effects studies on nontarget immature and adult arthropods [Crustacea, Insecta and Mollusca, including shrimp, damselfly beetle, tadpole] demonstrate 24- and 48- hour LC_{50} values >900 ppb[44,45]. Confirming these studies, other researchers have demonstrated that sensitive life stages of nontarget organisms, i.e., nymph and larvae, and nontarget aquatic organisms that are highly related to mosquitoes, i.e., dragonfly, are not affected by Methoprene up to 1,000 ppb[46].

Preliminary investigations by Cliburn[47] were reported on the effects of Methoprene on various life stages of different amphibian species (*B. woodhousei*, *R. catesbeiana* and *R. pipiens*). Acute studies on *R. catesbeiana* and *R. pipiens* larvae indicate LC_{50} values >10,000 ppb and *B. woodhousei* adult LC_{50} values >1,000 ppb (highest dose tested). Chronic studies on *B. woodhousei* indicate a 22 day LC_{50} >1,000 ppb and LC_{50} 1,000 ppb for *R. catesbeiana* and *R. pipiens*. No other adverse effects were reported.

Rate of release and data generated under laboratory and field conditions with Methoprene mosquito product formulations, including slow release briquet formulations, indicate a maximal rate of release of<= 4 ppb. Data on nontarget organism support margins of safety of >200 for nearly all organisms tested. Therefore, exposure to Methoprene will not reach levels which are toxic to aquatic non- target species either after acute or chronic exposure[48,49,50].

Based upon review of the data submitted to the Agency between 1993 and 1996, EPA concluded in 1996 that the following label changes should be implemented on all solid Methoprene mosquito products:

• Remove the label restriction “do not use in fish-bearing waters” from all briquet and pellet labels and

• Add the label warning “this product is toxic to aquatic dipteran (mosquitoes) and chironomid (midge) larvae” to all briquet and pellet labels.

To view the complete EPA RED document, follow the EPA link below to ‘m’ for Methoprene. http://www.epa.gov/pesticides/biopesticides/ingredients/index.htm#M. The methoprene data in the BMP and SEPA checklist has been updated to reflect the conclusions of the updated EPA RED fact sheet.

33. Commenter 3: Table 3 should list the environmental effects for each control agent in a consistent manner. A list of nontargets groups should be included. The statement "Nontoxic to most nontarget species" is too general. Also, control agents of different formulations with different release rates and persistence characteristics should be listed separately.
RESPONSE: The list of nontargets is included in Table 2 (p. 6) of the SEPA Checklist. It was not included in the BMP document for lack of space. The phrase “Nontoxic to most nontargets” is taken from EPA language. Release rates and persistence were noted in the column titled Application method(s) persistence and comments when that information was available.

34. Commenter 2: With reference to products listed in table number 3, additional formulations of Vectolex are registered in the state of Washington for use in *Culex* breeding habitats. The draft BMP recommends using an IPM approach, selecting treatments using the “most effective control method or combination of methods for the particular species of mosquitoes and the breeding area found by larvae surveys.” However, the proposed BMP document does not seem to evaluate the usefulness or appreciate the appropriateness of the use of chemical controls in an IPM mosquito and vector control program.

The information in Table 3 of this section implies that Abate (Temephos) is not a permitted insecticide for mosquito control. In fact Abate products, both liquid and granular formulations, are registered with the U.S. Environmental Protection Agency and with the Washington State Department of Agriculture for control of mosquito larvae in various non-potable, non-crop breeding habitats. The active ingredient, temephos, has been evaluated by the U.S. EPA, in consultation with the Department of Health and Human Services (HHS), for reregistration and has been deemed eligible for reregistration under Section 4 of the Federal Insecticide, Fungicide, and Rodenticide Act, as amended (FIFRA). “Temephos is effective against a wide spectrum of mosquitoes, including those that transmit Eastern equine encephalitis, St. Louis encephalitis, dengue fever, and West Nile virus. It is more effective than available alternatives in highly polluted water and tidal zones. As such, it is considered to be an important management tool in mosquito abatement programs."3

While Temephos is the only organophosphate with any appreciable mosquito larvicidal use, its role in an IPM program cannot be discounted. In many control situations where source reduction is not appropriate, Temephos may be the most effective control method in an environmentally and economically sound mosquito control program. In such sites as very highly polluted water or tidal zones, Abate products offer effective control while mitigating risk to nontarget aquatic species and the aquatic ecosystem when used in accordance with the Abate product label and the requirements of the Reregistration Eligibility Decision (RED). Mitigation measures adopted in the Temephos RED preclude significant exposure of sensitive nontarget species by limiting application rates and reapplication intervals. Specifically, use of Abate products is limited to: "non-potable water, standing water, moist areas, woodland pools, shallow ponds, edges of lakes, swamps, marshes, tidal waters, intertidal zones of sandy beaches, waters high in organic content, highly polluted water, catch basins and tire piles." "Maximum application rates may be used only in water high in organic content, mosquito habitats having deep water or dense surface cover, and where monitoring has confirmed a lack of control at typical rates." "This product may not be reapplied within 7 days of the date of the initial application unless monitoring indicates that larval populations have reestablished, or weather conditions have rendered initial treatments ineffective."4

We feel the language included in Table 3 of the draft BMP does not consider the likelihood of the exposure of nontarget species when the product is used appropriately, but instead overstates the environmental impact as though the product were misapplied. Instead, we recommend the Department of Ecology include in its BMP document language, as above, that mitigates environmental risk by reducing the potential for nontarget exposure. In addition, comments in Table 3 suggest that Abate products pose a significant risk to human health. While certain hazards to the pesticide handler/applicator are inherent to organophosphate products, these hazards do not address bystander or residential risk. EPA states in its Temephos RED document that "…because of its limited use pattern no significant exposure is expected to… the general population." [3]

In consideration of comments provided above regarding the application of Abate and the mitigation of environmental and health risk, we feel the Department should reconsider its position on conditionally allowing the use of Temephos products only in a declared emergency or in response to documented pesticide resistance within a population. The decision to apply a particular mosquito larvicide product is based on a sound IPM approach. This principle applies to Abate products as well as to the application of biorational products or larvicide oil. By limiting the application of a federally registered mosquito larvicide and removing the only tool available to effectively control mosquitoes in certain circumstances could result in disease transmission and ultimately human illness or death from vector borne disease. In addition, the permitted use of Abate solely in response to pesticide resistance is contrary to the fundamental concept of resistance management, which is a proactive philosophy designed to negate the development of resistance before it occurs. We respectfully request the department not limit the use of this effective public health product, so as not to limit the tools available in the arsenal against mosquitoes and mosquito-borne disease.

[3] http://www.epa.gov/oppsrrd1/REDs/temephos_red.htm#ExecutiveSummary
[4] http://www.epa.gov/oppsrrd1/REDs/temephos_red.htm#VB2

RESPONSE: The listing of typical products in table 3 is not meant to be exhaustive.

General permit condition S1 allows the use of malathion or temephos products labeled for aquatic use on mosquito larvae only under either of the following two conditions:

a. As a result of consultation between the Department of Agriculture and Department of Ecology and then only in response to the development of pesticide resistance within a population of mosquitoes. Monitoring of insecticide persistence and residuals shall be a condition of such approval.

b. As a result of consultation between the Department of Health and Department of Ecology in response to the development of a human health emergency as determined by the Washington State Department of Health.

Condition S4.2. of the permit specifies the use of malathion or temephos in a BMP/IMP plan.

> Following is the approved list of pesticide-based controls in the order of preference in which they should be considered in the mosquito control plan:
>
> - Bacillus thuringiensis israelensis (Bti)
> - Bacillus sphaericus (H-5a5b)
> - Methoprene Granular, Liquid, Pellet, or Briquet
> - Monomolecular Surface Films
> - Paraffinic white mineral oil. Paraffinic white mineral oil shall not be used in waters of the state unless:
>   a. The mosquito problem is declared a public health risk; or
>   b. The other control agents would be or are known to be ineffective at a specific treatment site; and
>   c. The water body is non-fish-bearing (consult Washington State Fish and Wildlife concerning fish and wildlife).
>
> 3. In developing the IPM plan, the permittee shall consult with local governments and state and federal agencies as needed.
>   a. Malathion or temephos shall be used only in response to a public health concern or documented development of resistance to all less toxic control methods and in accordance with S1

As noted above, the permit does not allow the use of temephos except under emergency situations. The permit is no longer open to appeal and the Department of Ecology would have to go through a major modification/appeal process to change this condition of the permit because it would result in a less stringent condition. In addition, because there are effective larvicides available that are less toxic to nontarget organisms and because the permit does not preclude the use of temephos when there is a public health concern, this condition will not be modified at this time.

35. Commenter 9: Table 3: One example is the Environmental Impacts associated with methoprene in regards to fish along with the Target Pest Label (pg 18). The information used in this section is not accurate and outdated.
RESPONSE: Comment noted. See response to comment 32.

36. Commenter 8: The IPM approach. There is no reference on the label of larvacides to the velocity of the wind when applying. Good common sense will be the best guide. There are many days that wind speeds are over 15 mph. Ground applications of granular and pellet material that is heavier will still work fine with a cyclone spreader. Small applications of liquid larvacide with a backpack will work with the nozzle low to the ground and the wind at your back.
RESPONSE: Comment noted.

36. Commenter 8: Methoprene is stated to be moderately toxic to warm-water, freshwater fish and slightly toxic to cold-water, freshwater fish. Your reference is to information dated March 1991. If you would research further you would find that all fish warnings on the label were removed in 1997. Updated and scientific evidence needs to be used when printing such a document about products.
RESPONSE: Comment noted. See response to comment 32.

37. Commenter 8: Where is it stated that BTI and Methoprene may inadvertently kill daphnids, copepods, mysid shrimp and others? Your #2 web site for information does not respond.

RESPONSE: The following is an excerpt from EPA's Pesticides: Biopesticides Fact Sheet. Note findings under Freshwater invertebrates: *Daphnia* (154-20) below.

G. ECOLOGICAL EFFECTS

The nontarget data requirements for *Bt israelensis* strain EG2215 were bridged from data submitted for other *Bt israelensis* registrations. *Bt israelensis* strain EG2215 has been positively identified as a typical *Bt israelensis* and it is unlikely that the toxicology of this microorganism will differ from other strains of *Bt israelensis*. However, the Agency [EPA] is concerned with the potential presence of heat labile exotoxin produced during the manufacturing process for all *Bt* active ingredients. For this reason, a *Daphnia* study (with a 10 day exposure period) will be required as a condition of registration for *Bt israelensis* strain EG2215. Should this test show significant lethality, a dose response *Daphnia* test must be performed to derive an LC_{50}. Pending the results of this assay, further nontarget species testing may be required by the Agency.

A summary of *Bt israelensis* toxicity to nontarget organisms is presented below:

Toxicity to Terrestrial Animals
Birds: mallard duck and bobwhite quail (154-16)

Cited studies indicate that *Bt israelensis* is not toxic or pathogenic to either of these species after acute or subacute testing.

Nontarget insects: green lace wing larvae, parasitic hymenoptera, predaceous Coleoptera (154-23)

Cited studies indicate that *Bt israelensis* shows little to no toxicity in any of the tested species.

Nontarget insects: honey bee (154-24)

Cited study demonstrates that *Bt israelensis* has minimal toxicity to honey bees.

Toxicity to Aquatic Animals

Freshwater fish: trout and bluegill (154-19)

Cited studies indicate no toxicity or pathogenicity associated with *Bt israelensis*.

Freshwater invertebrates: *Daphnia* (154-20)

Cited study indicates that *Bt israelensis* is moderately toxic to *Daphnia*. The use rates of all end use products formulated from *Bt israelensis* strain EG2215 will be evaluated prior to registration to determine the risk to nontarget aquatic invertebrates.

Estuarine and marine animals: grass shrimp, sheepshead minnow, copepod (154-21)

Cited studies indicate no toxicity or pathogenicity in these species associated with *Bt israelensis.*

Here is the link to the above information:
www.epa.gov/oppbppd1/biopesticides/ingredients/factsheets/factsheet_006476.htm

38. Commenter 8: It is referenced many times that an IPM program should use all aspects to control mosquitoes, including drainage and chemical, yet draining wetlands is not allowable under these management practices and the use of chemicals (organophosphates) is now prohibited unless a health emergency exists. It seems odd to suggest ways for an IPM program to run and give information that is now against the law.
RESPONSE: Wetlands perform at least three classes of functions: hydrologic functions (i.e., flood peak reduction, shoreline stabilization, or groundwater exchange), water quality improvement (sediment accretion, filtration or nutrient uptake), and food-chain support (structural and species diversity components of habitat for plants and animals including threatened endangered and sensitive species.) Given the critical functions wetlands perform, Ecology does not condone draining wetlands as a method for mosquito control.

39. Commenter 8: Malathion is not listed in the table as being a product that could be used in an emergency use only. Malathion 8 is labeled and registered as a larvacide as well as an adulticide. Even if it is only in an emergency, it still is a labeled product. It can actually be applied on more food products than almost any other chemical at much higher rates than on mosquitoes.
RESPONSE: Malathion 8EC Insecticide is labeled for use on mosquito larvae and can be used under the permit as specified for temephos. Please refer to response to comment 34. The BMP will be amended to include this larvicide.

40. Commenter 8: It is also mentioned on page 21 that adulticiding should only be considered when there is evidence of mosquito-borne epizootic activity at a level suggesting high risk of human infection, dead birds and mammals and etc. Many people are allergic to mosquito bites and have a tremendous reaction and require a doctor's care. Without some sort of assistance or control, it can be very serious. Adulticiding has its place, but from the information given it is stating that it would be in extremely rare cases. That is not a fact! It is part of an IPM program. It is not the total answer to just adulticide, but it is one of the tools in an IPM program. That is a fact.
RESPONSE: Ecology agrees that adulticiding may be part of a mosquito control approach and has included adulticiding control methods in the BMP, even though we do not regulate terrestrial pesticide applications.

41. Commenter 9: On (pg 21) is it the Departments of Ecology stance that if there where an outbreak of disease near a ESA stream that no adulticides may be used? The third paragraph, last sentence, needs to be addressed differently. It was also my understanding that DOE does not regulate adulticides. The appropriate department to insert in this paragraph would be the Washington State Department of Agriculture.
RESPONSE: Adulticides not labeled for use in water cannot be used in water whether ESA listed species are present or not. WSDA has reviewed and contributed to the BMP plan.

42. Commenter 5: In table #4, page 22, reference is made to Cythion ULV. Cythion is no longer the trade name used for our malathion. The correct designation should be Fyfanon ULV. Cythion was the old American Cyanimid product which was typically labeled at 93% active ingredient. Due to production improvement, Cheminova was able to increase the purity (malathion content) of the Fyfanon ULV product to 96.5% nominal concentration. The batches of Fyfanon ULV we produce typically range from 96 - 97.5% purity. Our oral LD 50 is now listed as 5500 mg/kg on freshly produced material. By increasing the purity, the inert profile has decreased thereby decreasing the oral toxicity.

Also in table #4 it is indicated malathion is a "Product of last resort". Please let me know why this designation has been assigned to malathion as there is currently no water setback on our Fyfanon ULV EPA Registered label. If there is a particular reason for this designation we would like to be able to comment.

In addition, the cost for malathion per oz. indicated may, in actuality, be somewhat less than this figure.

RESPONSE: The change to product name Fyfanon ULV has been noted and made. Malathion is a product of last resort due to impacts to nontarget organisms as compared with other products.

43. Commenter 6: ALL of the products listed in table 4 on page 22 are ULV products. All of these products produce droplets that are intended to remain in suspension in the air so they can impinge on the adult mosquitoes in order to kill them. Hence, the note at the bottom of the page about organophosphate products is not correct. It should either be taken out, or modified to include **ALL of the products listed in table** 4.

Only Natural **Pyrethrin** and **malathion** are labeled for use on mosquitoes in a pasture setting. This is due to crop residue tolerances established for them by the USDA, IR-4 and EPA. SEE EPA WEBSITE FOR CROP TOLERANCE DATA FOR BOTH OF THESE PRODUCTS.

Mosquito species such as *Aedes vexans* and *Aedes nigromaculis* are two examples of competent vector species found in many pasture settings in Eastern Washington. These two species of mosquitoes are commonly found in close association with pasture environments. Both Pyrethrin and malathion are used in these settings to control adult mosquitoes.

All of the products listed in table 4 on page number 22 are labeled for **terrestrial use**. Why then is WA DOE taking the lead on specifying which adulticides can be used? Why is the WA STATE DEPARTMENT OF AG not consulting with EPA REGION 10 on this matter?

Again adulticides are designed for terrestrial use. Many studies have been conducted to look at the potential impact of ULV products to nontarget species in both **terrestrial** and **aquatic** environments. Given the wide body of information available on the toxicity of **all** these products it appears that WA STATE DOE OR WA DEPARTMENT OF AG has given NO scientific basis for limiting the use of these product against adult mosquitoes. For example, A recent paper Titled: **EFFECTS OF ULTRA-LOW VOLUME PYRETHRIN, MALATHION AND PERMETHRIN ON NONTARGET INVERTEBRATES, SENTINEL MOSQUITOES, AND MOSQUITOFISH IN SEASONALLY IMPOUNDED WETLANDS (JENSEN, LAWLER AND DRITZ-1997).** Published in the Journal of the American Mosquito Control Association 15(3): 330-338, 1999. Shows that the use of ULV adulticides in a seasonal wetland environment has No significant impact on the entire system. This work was done at the University of California-Davis and it was done with the cooperation of a variety of agencies. In addition, this paper sites an entire body of credible research about the use of Pyrethrin, malathion and permethrin and their potential impacts on various organisms in and around aquatic environments. NO REFERENCES ARE MADE TO ANY DATA, WHICH WOULD SUPPORT OR NOT SUPPORT USING ULV PRODUCTS TO CONTROL ADULT MOSQUITOES.

All labels for the products listed in table 4 on page 22 give specific directions for use. The EPA and FIFRA regulate what language and statements can be contained on a label. Under FIFRA it is not legal for an individual state to alter or change the use of a given pesticide. This can only be done under a section 18 or 24 (c) for products, which are not labeled for a specific use. HOWEVER, on page number 21 under BMPs for adulticiding the document states specific conditions which must be followed when applying adulticides. Where did this information come from? Did the WA STATE DEPARTMENT OF ECOLOGY AND AG CONSULT WITH EPA ON THIS MATTER?

Also, legal president has been set on this matter by EPA pesticide branch region number 10 in 1999. In this case EPA stated clearly that "Labels broadly provide for legal use in outdoors residential and recreational areas where adult mosquitoes are present." Further it addressed concerns about use near water EPA made the following comments. "Lastly there is the issue of use "around" inlets, creeks and swamps…. The label states "Do not apply directly to water or to areas where surface water is present or intertidal areas below mean high tide mark. Since this is a mosquito adulticide designed to be applied as a space fog where mosquitoes are present in annoying numbers, the Insecticide Branch believes that the label provides for some discretion on the parts of the professional applicators and the mosquito abatement authorities. Why has the WA STATE DEPARTMENT OF ECOLOGY OR WA DEPARTMENT OF AG NOT consulted with the EPA on this matter?

RESPONSE: All of the products in Table 4 are now listed as ULV organophosphates. Ecology included this section on terrestrial products because mosquito control experts told us a mosquito control plan was not complete without them. We are not attempting to regulate the use of these products but only include them in a mosquito control plan that was developed as a service to those who choose to use them. Those interested in modifying their use of adulticides from this plan are welcome to do so.

44. Commenter 9: In the Comments section of Table 4 (pg22), there are references to certain products and their effectiveness, which I disagree. Just an example would be Scourge and the quote of "Has not performed well in this area." An applicator that has no idea on how to apply this product would find it to be ineffective but with proper application the product does work. These are very debatable statements that are probably best left out of a State document. Also, Cythion is not made anymore. A product called Fyfannon can be entered in its place.
RESPONSE: As with all products, there is site specific variability. The comment will be amended. The product name was updated on the table.

45. Commenter 2: The draft document implies that contracted mosquito control activities are conducted by seasonal and untrained contract personnel. ALL Commercial applicators are trained and licensed under the same standards as mosquito control district employees and applicators. Many contract applicators, in fact, must also be trained and licensed under state guidelines and many have extensive experience in mosquito surveillance and control. Seminars, conferences and other educational resources are often sponsored and presented by contract mosquito control professionals.

The implication that a community may experience an emergency only when they have not prepared for mosquito control as outlined in the draft document is not necessarily an accurate statement. Communities may do everything as proposed and can still have a disease epidemic occur in their area as experienced by many ongoing mosquito control districts around the country when WNV appeared. CDC guidelines indicate that in an emergency situation, "Delaying adulticide applications in areas with these surveillance indicators until human cases occur negate the value and purpose of the surveillance system."
RESPONSE: Comment noted. Please see response to comment 40.

46. Commenter 1: Page 21 BMPs for adulticides:

1) Smoke is not commonly and hard to use in the dark.
4) Not all adulticides require set backs from water. Dibrom, malathion, Scourge and Anvil do not. Permethrin products do have a 100 foot setback. There is no such thing as a 50 foot or 150 foot setback.

RESPONSE: We do not recommend spraying after dark. When setbacks or buffers are not required by the label we recommend applicators set their own setbacks to prevent drift in water on an as-needed basis.

47. Commenter 2: Most aerial applications of adulticides would occur in early morning and evening during darkness and the use of smoke for determining wind parameter would not be particularly effective. Due to the many diverse species in the state of Washington, the optimum application parameters should be determined by the host seeking habits of targeted species. The statement in the draft regarding spray buffers as "outside the maximum equipment spray swath" directly contradicts the U.S. EPA interpretation that the spray buffer begins at the point of application.
As the registrant of Anvil in Washington State, we would like to have table 5 include the following information which is missing from the draft document:
- Labeled use rates
Anvil labeled use rates are 0.0012 lb – 0.0036 lbs active ingredients (ai) per acre
- Comments:
Anvil has been tested in Washington State for efficacy. For more information contact Mr. Jim Thompson at Grant County Mosquito Control, Moses Lake, Washington.
RESPONSE: Please see response to comment 46. Label use rates for Anvil have been added to the table.

48. Commenter 4: There seems to be a contradiction in two of the purposes evident in this section (BMPs for adulticides listed on page 21) of the BMPs document. On one hand is the recommendation to spray at dusk when inversions start and when mosquitoes are active and pesticide efficacy will be enhanced and on the other hand the BMPs for adulticides attempts to establish guidelines for preventing drift into sensitive areas when spraying at dusk means spraying during an inversion, which is one of the worst times to spray because of the likelihood of drift.

Many of the adulticide labels that allow or advise spraying at dusk when mosquitoes are active and when meteorological conditions are conducive to keeping the spray close to the ground. One label stated to make the applications during inversions. Other labels advise not making applications when wind speed exceeds a given velocity. Weather data (from WSU PAWS) for north-central and south-central Washington confirm that the generally accepted beliefs about inversions (e.g. start and stop times, stable air conditions, low wind speed, highly variable wind direction) are true for Washington (at least in north-central and south-central Washington). In 2002, inversions began in the spring from one to several hours before dusk and ended one to several hours after sunrise. Stable air conditions and low wind speeds (usually 0-2 mph but occasionally up to 5 mph) are typical of inversion conditions. Wind direction is more variable at low wind speed compared to high wind speed. For wind direction, there is a measurable difference in direction variability at 0-2 mph wind velocity compared to even 5 mph.. The existing weather data suggests that if mosquito adulticides are applied at dusk they will be applied during an inversion and that the distance and direction that drift will move is highly variable and unpredictable.

It is generally accepted that pesticide applications during inversions are more prone to drift and that pesticides applied during inversions may drift for miles, meaning that the stream spray buffers mentioned in the BMPs are unrealistic. Many non-mosquito pesticide labels prohibit or advise against applications during inversions. Some pesticide labels prohibit making applications when wind speed is less than 2 mph. Washington has WACs that prohibit application of specific pesticides during inversions precisely because history has shown that many drift complaints arise from applications made during inversions. Some of the WACs prohibit applications from 3 hours before sunset to 1 hour after sunrise because it is commonly accepted that this is when inversions exist. Aerial applicators are prohibited from applying paraquat until the temperature inversion ceiling is at least 1000 ft (their aircraft must be equipped with a thermometer so that they can detect the inversion ceiling). Complicating the issue of adulticides applied during inversions is the issue of droplet size. The small droplets typical of aerosols, fogs, and ultra-low volume applications are much more prone to drift than larger droplets applied at higher solution volumes. Investigations of pesticide drift conducted by the Washington State Department of Agriculture confirm that drift is a likely consequence of applications made during inversions. It is very likely that mosquito adulticides applied at dusk will be prone to drift and that the direction and distance of the drift could be unpredictable and it certainly will not be confined to a 50- to 150-ft buffer between the maximum swath width and a fish-bearing stream or any other sensitive or nontarget area.

Regarding the comment on the elevations of air inversions ("air inversions go from 50 to 600'"): the ceiling of a temperature inversion can vary from a few millimeters to thousands of meters above the surface of the earth. PAWS data shows that temperature inversions can be detected at a difference in elevation of less than 30 ft. In a strong inversion, temperature differences of several degrees can be detected in this 30 ft. Spray droplets are not forced down by an inversion, they are simply prevented from moving higher than the inversion ceiling by limited vertical mixing. Since a temperature inversion exists when temperature increases with elevation, it is impossible to spray under an inversion; however, it is possible to spray under the temperature inversion ceiling.

Given that pesticide applications during temperature inversions are prone to drift and that the drift direction and distance are unpredictable, it is unlikely that an adulticide can be applied in the vicinity of sensitive areas such as fish-bearing streams or people on the pesticide sensitive registry without subjecting the sensitive areas to drift. I recommend putting strong language in this section regarding the likelihood of drift and the necessity to find alternative means of controlling mosquitoes other than using adulticides.
RESPONSE: Comment noted.

49. Commenter 1: (Page 22 Table 4) If you are to list brands then I would suggest listing all brands such as
Permethrin – Biomist, Kontrol, Permanone, Aqua Reslin
Comments: should read 100 ft setback.
Pyrethrin – MGK 25-5, Pyrenone 25-5
Comments: No setback to water, approved for crop and pasture application.
Resmethrin (not SBP1382) – Scourge
Comments: are not accurate to say it has not performed well. Dr. Whitworth does not use true ulv equipment and therefore cannot judge its effectiveness. Scourge is one of the most widely used and effective pyrethroids compounds. No setback to water.
Cythion is no longer sold – should read Fyfanon ULV
Comments: not accurate to say product of last resort. One of the few approved over crop and pasture.
Sumithrin – has been tested and used in the Northwest. No setback to water.
Naled- Need to add Naled to the list of approved products, brand names Dibrom and Trumpet. One of the most effective aerial adulticides used in mosquito control today. Approved over crop and pasture. Not recommended for ground ULV use.

Cost is typically based on cost per acre to apply rather than cost per ounce. ULV label rates have ranges and you should use the entire range on the label, not just 4 ounces etc. All ULV products require small particles and intended drift is a measure of effectiveness.
RESPONSE: The typical products column is not meant to be exhaustive. The table has been updated with your information. Thank you.

50. Commenter 8: Anvil on page 22 (Table 4) has been used in Washington and there is data to back that up. Again facts are important to this document. Fyfanon ULV is not susceptible to drift any more than the other product. The same equipment is used to disperse this product as any other adulticide. The wind, temperature and applicator control the drift of these products.
RESPONSE: Comment noted. The comment in the table for Anvil has been amended.

Comments on the Determination of Nonsignificance Sepa Checklist

51. Commenter 11: WDFW feels that this should at least be a Mitigated Determination of Nonsignificance. The application of pesticides, i.e., Bti, is to kill mosquito larvae. Mosquito larvae are prey species for swallows, bats, swifts, and other insectivorous birds. Even if the application is limited it will impact local, and sometimes fragile, local populations.
RESPONSE: Comment noted. These larvicides were reviewed through SEPA when the permit was issued for draft review. Larvicide use is conditioned by FIFRA, the permit, and now these BMPs. We feel their use under the permit warrants a DNS

52. Commenter 3: The checklist should list the more important BMPs for mosquito control and attach the draft mosquito control BMP document, noting the pages where the BMPs are referenced. Since the emphasis is on BMPs, they should be described in the checklist itself and not just referred to in a separate document.
RESPONSE: The SEPA checklist does reference the BMP document, and the final BMP document will be attached to the checklist.

53. Commenter 3: There should be a description of personal protection measures in the checklist.
RESPONSE: Those measures are referred to in the BMP.

54. Commenter 3: Section 7 (Environmental Health) should list public education and communication with adjacent landowners as methods to reduce or control environmental health hazards. This section requires "communication with farmers" only.

RESPONSE: Comment noted. The BMPs do outline public education and communication appropriate to the area of control as a preliminary step in the IPM approach.

55. Commenter 3: The checklist should note that detention ponds are among the structures that may receive larvacide treatment.
RESPONSE: Agreed. They have been added.

56. Commenter 6: WHAT IS AN ESA STREAM? ARE THEY LOCATED WHERE mosquito adulticides are used? Can adult mosquitoes move from hatch sites to urban/suburban areas where humans reside? WA STATE DOE and WA DEPT OF HEALTH or WA DEPT OF AG does not appear to have a clear understanding of how, where or when ULV adulticides are used. ARE THESE AGENCIES prepared to explain to the general public why a NO action stance was taken when a vector borne disease such as West Nile Virus results in illness and death in the human in WA STATE?
RESPONSE: ESA streams are streams that support ESA listed species. Adulticides are not applied to water, so there should not be an exposure concern.

57. Commenter 11: Under #5 Animals, b., you state that "EPA is developing a program….to identify all pesticides whose use may cause adverse impacts on endangered and threatened species…" The assumption is that this only will cover federal species. There are a number of state-listed species that may not be identified by their program. It most likely will not include priority species (including state recreational species valued by the citizens of this state) that may not be endangered but could be given there is no direction in this plan that discusses under what circumstances will these measures be used. The use of Bti or malathion, particularly, will have significant impacts on state-listed species. State-listed butterflies and moths may be impacted by Bti. Malathion is an organophosphate and is highly toxic to fish. EXTOXNET (http://ace.ace.orst.edu/info/extoxnet/pips/malathio.htm) states the following concerning fish impacts:

> Malathion has a wide range of toxicities in fish, extending from very highly toxic in the walleye (96-hour LC50 of 0.06 mg/L) to highly toxic in brown trout (0.1 mg/L) and the cutthroat trout (0.28 mg/L), moderately toxic in fathead minnows (8.6 mg/L) and slightly toxic in goldfish (10.7 mg/L) [13,8,16]. Various aquatic invertebrates are extremely sensitive, with EC50 values from 1 ug/L to 1 mg/L [28]. Malathion is highly toxic to aquatic invertebrates and to the aquatic stages of amphibians. Because of its very short half-life, malathion is not expected to bioconcentrate in aquatic organisms. However, brown shrimp showed an average concentration of 869 and 959 times the ambient water concentration in two separate samples. (EXTOXNET, June 1996).

It also notes that malathion is also toxic to honeybees (EXTOXNET, Ibid). This could impact agricultural areas that rely on honeybees for propagation.

Applications of petroleum and other chemicals will likely directly affect amphibians, in addition to removal of food sources. Again, it is important to recognize state priority species, including those that are state-listed as sensitive, threatened or endangered, or of recreational value may not be identified by EPA's program. The Checklist needs to make sure it acknowledges that mitigation sequencing will be followed (avoid, reduce, mitigate), when application is needed, and to identify when is it critical to control mosquito populations based on the need established in the plan (see discussion of Need and Purpose in BMP Introduction).
RESPONSE: Comment noted. If WDFW would like to designate waters that should be restricted from permitted pesticide applications they are welcome to submit that data to Ecology for our consideration. Ecology has requested this data repeatedly.

Appendix

Flow Charts for Mosquito BMPs

IPM Controls for Mosquitoes in Snowmelt Sites

Where appropriate, stock ponds with no outlet with predators i.e., mud minnows, stickleback, perch, tadpoles, goldfish, dragonfly larvae, diving beetles, back swimmers, and front swimmers.

Conduct larvae surveys and/or trap adult mosquitoes to monitor for action thresholds and vector species. Use other surveillance data as available.

Note: In many high mountain meadows and also at lower levels mosquitoes breed in pools caused by snow melt. Development may require several weeks at higher elevations. *Aedes communis, A. cinereus, Ochlerotatus hexodontus, O. fitchii*, and O. *increpitus* are the most common species found in these locations. Usually there is only one generation per year, but the large numbers that may be produced are a severe annoyance to those who are working or seeking recreation in these areas. Elimination of breeding areas by drainage or maintenance of constant water levels is practical in some situations. Insecticide applications might have to be made by hand or by plane because of inaccessibility to heavy ground equipment.

These larvicides, placed in order of toxicity, are permitted for use in WA ST. See Table 3 for costs, etc.

1. Bti for 1 – 30 day control in water with low organic content. Controls actively feeding larvae.
2. BS for 1 – 30 day control in water with high organic content. Controls actively feeding larvae.
3. Methoprene for 30+ days of control. Briquets best for flowing water. Controls larvae and pupae.
4. Monomolecular surface films for 22+ days of control. Winds may affect control. Controls larvae, pupae and adult mosquitoes. Can be used in potable water. Organic content of water does not affect control.
5. Larvicidal oils for 15 hours of control. Control larvae and pupae. Organic content of water does not affect control.

Where breeding sites are inaccessible or too large to treat, selective ULV (ultra low volume) fogging to protect areas of human activity may be more ecological and practical. Many products are registered for *terrestrial* use in WA ST. Please consult Table 4 for listing of products.

Conduct surveillance to track the effectiveness of the control measures. Record results and adjust control strategies as needed.

IPM Controls for Mosquitoes in Floodwater Sites

Minimize breeding sites if possible. Large *Aedes vexans* and *Ochlerotatus sticticus* breeding areas have been managed efficiently in the past by controlling water levels above Bonneville Dam. Dikes have prevented flooding in other areas. Clearing of brush has been of value in some locations. However, control of the major section of these types of breeding areas must often be accomplished with insecticide applications.

Conduct larvae surveys and/or trap adult mosquitoes to monitor for action thresholds and vector species. Use other surveillance data as available.

Note: *Aedes vexans* and *Ochlerotatus sticticus* develop in large numbers along the borders of the Columbia and other rivers, creating one of the most important mosquito problems in this region. The larvae hatch in the spring or early summer when the streams overflow areas such as willow and cottonwood swales where the eggs have been laid. The eggs of these species are dormant when temperatures remain below 45-50º F. Partial dormancy of the eggs may continue until sometime in June so that only some of the eggs are hatched by floods occurring in April or May. In some seasons, the larger rivers may rise, recede, and rise again to cover the same egg beds and produce an additional hatch. In other seasons, two or three successive rises may occur, each of which is higher than the last. Females that emerge in the first hatch may lay eggs that will hatch in the second or third rises of the river. Most of the eggs are laid between the 10 and 20 foot levels, and some of the eggs that are not flooded during a series of low flood crest years remain viable for as long as four years.

These larvicides, placed in order of toxicity, are permitted for use in WA ST. See Table 3 for costs, etc.

1. Bti for 1 – 30 day control in water with low organic content. Controls actively feeding larvae.
2. BS for 1 – 30 day control in water with high organic content. Controls actively feeding larvae.
3. Methoprene for 30+ days of control. Briquets best for flowing water. Controls larvae and pupae.
4. Monomolecular surface films for 22+ days of control. Winds may affect control. Controls larvae, pupae and adult mosquitoes. Can be used in potable water. Organic content of water does not affect control.
5. Larvicidal oils for 15 hours of control. Control larvae and pupae. Organic content of water does not affect control.

Where breeding sites are inaccessible or too large to treat, selective ULV (ultra low volume) fogging to protect areas of human activity may be more ecological and practical. Many products are registered for *terrestrial* use in WA ST. Please consult Table 4 for listing of products.

Conduct surveillance to track the effectiveness of the control measures. Record results and adjust control strategies as needed.

IPM Controls for Mosquitoes in Irrigated Lands

Eliminate mosquito breeding sites by using physical controls

1. Minimize standing water in fields so that it does not lie fallow for more than four days by improving drainage channels and grading.
2. Tail waters should not be allowed to accumulate for more than four days at the end of the field.
3. Keep ditches clean of heavy vegetation to promote more rapid drainage.
4. Have ditches repaired to reduce seepage to the extent practicable (elevated water tables can produce unintended standing water in fields).
5. Minimize flood and rill irrigation practices to the extent practicable.
6. Avoid over-watering.

Conduct larvae surveys and/or trap adult mosquitoes to monitor for action thresholds and vector species. Use other surveillance data as available.

Note: Breeding places for several mosquito species are provided by irrigation water. *Aedes dorsalis, A. vexans, Ochlerotatu melanimon*, and *Ochlerotatus nigromaculis* are among the most important species that may develop when water is applied and stands for a week or 10 days. Other species such as *Culex tarsalis, Culiseta inornata,* and *Anopheles freeborni* may be produced if water remains for longer periods.

Stock ponds with *no outlet* with predators i.e., mud minnows, stickleback, perch, tadpoles, goldfish, dragonfly larvae, diving beetles, back swimmers, and front swimmers as appropriate.

These larvicides, placed in order of toxicity, are permitted for use in WA ST. See Table 3 for costs, etc.

1. Bti for 1 – 30 day control in water with low organic content. Controls actively feeding larvae.
2. BS for 1 – 30 day control in water with high organic content. Controls actively feeding larvae.
3. Methoprene for 30+ days of control. Briquets best for flowing water. Controls larvae and pupae.
4. Monomolecular surface films for 22+ days of control. Winds may affect control. Controls larvae, pupae and adult mosquitoes. Can be used in potable water. Organic content of water does not affect control.
5. Larvicidal oils for 15 hours of control. Control larvae and pupae. Organic content of water does not affect control.

Where breeding sites are inaccessible or too large to treat, selective ULV (ultra low volume) fogging may be more ecological and practical. Many products are registered for *terrestrial* use in WA ST. Please consult Table 4 for listing of products.

Conduct surveillance to track the effectiveness of the control measures. Record results and adjust control strategies as needed.

IPM Controls for Mosquitoes in Ponds, Shoreline Sites

Where appropriate, stock ponds with native predators i.e., mud minnows, stickleback, perch, tadpoles, goldfish, dragonfly larvae, diving beetles, back swimmers, and front swimmers.

Conduct larvae surveys and/or trap adult mosquitoes to monitor for action thresholds and vector species. Use other surveillance data as available.

Note: The mosquitoes that lay their eggs on the water are usually found where water is present continuously during the season or at least for several days. Such locations include natural permanent ponds, including still waters along the borders of lakes and rivers sheltered from wave action and currents with some degree of vegetation, log ponds, tree holes, semi-permanent ponds and wetlands of various types, and artificial containers. *Culex tarsalis, C. pipiens, C. peus, Anopheles freeborni, A. punctipennis, Culiseta incidens,* and *C. inornata* are commonly found in such places. *C. tarsalis* and *C. pipiens* develop in large numbers in log ponds. *C. pipiens* also develops in large numbers in sewer drains, catch basins, and water left in artificial containers. *Coquillettidia perturbans* are found in permanent water in wetlands, swamps and marshes that have emergent or floating vegetation. Insecticides are often used effectively to control most of these species, except those breeding in artificial containers that can be emptied. Larvae of *C. perturbans* are difficult to control because they are attached to the roots of plants.

These larvicides, placed in order of toxicity, are permitted for use in WA ST. See Table 3 for costs, etc.

1. Bti for 1 – 30 day control in water with low organic content. Controls actively feeding larvae.
2. BS for 1 – 30 day control in water with high organic content. Controls actively feeding larvae.
3. Methoprene for 30+ days of control. Briquets best for flowing water. Controls larvae and pupae.
4. Monomolecular surface films for 22+ days of control. Winds may affect control. Controls larvae, pupae and adult mosquitoes. Can be used in potable water. Organic content of water does not affect control.
5. Larvicidal oils for 15 hours of control. Control larvae and pupae. Organic content of water does not affect control.

Where breeding sites are inaccessible or too large to treat, selective ULV (ultra low volume) fogging to protect areas of human activity may be more ecological and practical. Many products are registered for *terrestrial* use in WA ST. Please consult Table 4 for listing of products.

Conduct surveillance to track the effectiveness of the control measures. Record results and adjust control strategies as needed.

IPM Controls for Mosquitoes in Artificial Containers

1. Empty or turn over anything that holds standing water—old tires, buckets, wheelbarrows, plastic covers, and toys.
2. Change water in birdbaths, fountains, wading pools and animal troughs weekly.
3. Drill holes in the bottoms of containers that are left outdoors.
4. Clean and chlorinate swimming pools that are not in use and be aware that mosquitoes can breed in the water that collects on swimming pool covers.
5. Aerate ornamental pools and use landscaping to eliminate standing water that collects on your residence; mosquitoes can potentially breed in any stagnant puddle that lasts more than 4 days.
6. Recycle unused containers—bottles, cans, and buckets that may collect water.
7. Make sure roof gutters drain properly, and clean clogged gutters in the spring and fall.

Where appropriate, stock ornamental ponds with predators goldfish mud minnows, stickleback, perch, tadpoles, goldfish, dragonfly larvae, diving beetles, back swimmers, and front swimmers.

Conduct larvae surveys and/or trap adult mosquitoes to monitor for action thresholds and vector species. Use other surveillance data as available.

Note: The mosquitoes that lay their eggs on the water are usually found where water is present continuously during the season or at least for several days. Such locations include natural permanent ponds, including still waters along the borders of lakes and rivers sheltered from wave action and currents with some degree of vegetation, log ponds, tree holes, semi-permanent ponds and wetlands of various types, and artificial containers. *Culex tarsalis, C. pipiens, C. peus, Anopheles freeborni, A. punctipennis, Culiseta incidens,* and *C. inornata* are commonly found in such places. *C. tarsalis* and *C. pipiens* develop in large numbers in log ponds. *C. pipiens* also develops in large numbers in sewer drains, catch basins, and water left in artificial containers.

These larvicides, placed in order of toxicity, are permitted for use in WA ST. See Table 3 for costs, etc.
1. Bti for 1 – 30 day control in water with low organic content. Controls actively feeding larvae.
2. BS for 1 – 30 day control in water with high organic content. Controls actively feeding larvae.
3. Methoprene for 30+ days of control. Briquets best for flowing water. Controls larvae and pupae.
4. Monomolecular surface films for 22+ days of control. Winds may affect control. Controls larvae, pupae and adult mosquitoes. Can be used in potable water. Organic content of water does not affect control.
5. Larvicidal oils for 15 hours of control. Control larvae and pupae. Organic content of water does not affect control.

Where breeding sites are inaccessible or too large to treat, selective ULV (ultra low volume) fogging to protect areas of human activity may be more ecological and practical. Many products are registered for *terrestrial* use in WA ST. Please consult Table 4 for listing of products.

Conduct surveillance to track the effectiveness of the control measures. Record results and adjust control strategies as needed.

Marshes, Estuaries and Wetlands
IPM Controls for Mosquitoes

Conduct larvae surveys and/or trap adult mosquitoes to monitor for action thresholds and vector species. Use other surveillance data as available.

Note: Coquillettidia perturbans are found in permanent water in wetlands, swamps and marshes that have emergent or floating vegetation. *Culex tarsalis, C. pipiens, C. peus, Anopheles freeborni, A. punctipennis, Culiseta incidens,* and *C. inornata* are commonly found where water is present continuously during the season or at least for several days.

Stock wetlands with amphibian larvae, aquatic salamanders, and small fish, if appropriate.

Use larvicides only when needed to protect human health. The following products permitted for use are listed in the order of least to greatest toxicity.

1. Bti for 1 – 30 day control in water with low organic content. Controls actively feeding larvae.
2. BS for 1 – 30 day control in water with high organic content. Controls actively feeding larvae.
3. Monomolecular surface films for 22+ days of control. Winds may affect control. Controls larvae, pupae and adult mosquitoes. Can be used in potable water. Organic content of water does not affect control.
4. Methoprene for 30+ days of control. Briquettes best for flowing water. Controls larvae and pupae.
5. Larvicidal oils for 15 hours of control. Control larvae and pupae. Organic content of water does not affect control.

Where breeding sites are inaccessible or too large to treat, selective ULV (ultra low volume) fogging to protect areas of human activity may be more ecological and practical. Many products are registered for *terrestrial* use in WA ST. Please consult Table 4 for listing of products.

Conduct surveillance to track the effectiveness of the control measures. Record results and adjust control strategies as needed.

Note: Do NOT drain or fill wetlands. Wetlands perform at least three classes of functions: hydrologic functions (i.e., flood peak reduction, shoreline stabilization, or groundwater exchange), water quality improvement (sediment accretion, filtration or nutrient uptake) and food-chain support (structural and species diversity components of habitat for plants and animals, including threatened endangered and sensitive species.) Given the critical functions wetlands perform Ecology does not condone draining wetlands as a method for mosquito control.

IPM Controls for Mosquitoes in Tidal Water Sites

Conduct larvae surveys and/or trap adult mosquitoes to monitor for action thresholds and vector species. Use other surveillance data as available.

Note: *Aedes dorsalis* is the only species that can breed in large numbers in both fresh and salt water in the Northwest. The larvae develop in some coastal areas where potholes are filled by the higher tides or where water levels fluctuate in permanent or semi-permanent pools. Leveling, drainage, or similar practices are effective in preventing breeding, but such areas must be properly maintained. *Ochlerotatus togoi* has also been found in coastal areas including San Juan, Island, Skagit, Kitsap, and Mason counties. Larvae of this species have been found in pools of pure seawater along rocky shorelines.

These larvicides, placed in order of toxicity, are permitted for use in WA ST. See Table 3 for costs, etc.

1. Bti for 1 – 30 day control in water with low organic content. Controls actively feeding larvae.
2. BS for 1 – 30 day control in water with high organic content. Controls actively feeding larvae.
3. Methoprene for 30+ days of control. Briquets best for flowing water. Controls larvae and pupae.
4. Monomolecular surface films for 22+ days of control. Winds may affect control. Controls larvae, pupae and adult mosquitoes. Can be used in potable water. Organic content of water does not affect control.
5. Larvicidal oils for 15 hours of control. Control larvae and pupae. Organic content of water does not affect control.

Where breeding sites are inaccessible or too large to treat, selective ULV (ultra low volume) fogging to protect areas of human activity may be more ecological and practical. Many products are registered for *terrestrial* use in WA ST. Please consult Table 4 for listing of products.

Conduct surveillance to track the effectiveness of the control measures. Record results and adjust control strategies as needed.

IPM Controls for Mosquitoes in Stormwater Systems

Reduce mosquito habitat as much as possible by design.

If possible, engineer modifications without compromising the facility's function to reduce mosquito habitat, i.e., change the flow rate, scarifying the pond bottom where it is no longer infiltrating as originally designed or enhance drainage by some other method. Eliminating low spots that collect small amounts of standing water and altering vegetation may also be options.

Conduct larvae surveys and/or trap adult mosquitoes to monitor for action thresholds and vector species. Use other surveillance data as available.

Year-around wet ponds, regional ponds and bio-swales

Marshes and wetlands

Temporary wet ponds, ditches and bio-swales

Catch basins, underground vaults

Stock ponds w/ no outlet w/ predators i.e., mud minnows, stickleback, perch, tadpoles, goldfish, dragonfly larvae, diving beetles, back swimmers, and front swimmers if possible.

Stock with amphibian larvae, aquatic salamanders, and small fish, if appropriate.

Note: See Table 1 for disease vector mosquito species associated with drainage control systems.

These larvicides, placed in order of toxicity, are permitted for use in WA ST. See Table 3 for costs, etc.

1. Bti for 1 – 30 day control in water with low organic content. Controls actively feeding larvae.
2. BS for 1 – 30 day control in water with high organic content. Controls actively feeding larvae.
3. Methoprene for 30+ days of control. Briquets best for flowing water. Controls larvae and pupae.
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5. Larvicidal oils for 15 hours of control. Control larvae and pupae. Organic content of water does not affect control.

Where breeding sites are inaccessible or too large to treat, selective ULV (ultra low volume) fogging to protect areas of human activity may be more ecological and practical. Many products are registered for *terrestrial* use in WA ST. Please consult Table 4 for listing of products.

Conduct surveillance to track the effectiveness of the control measures. Record results and adjust control strategies as needed.